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Since the start of Operation Enduring Freedom in 2001, over 42,063 patients have been transported by the United States Air Force aeromedical evacuation system. Critical Care Air Transport Teams (CCATTs) provide care for 5-10% of the injured and ill warriors that are transported on military cargo aircraft to definitive treatment facilities. The purposes of this study were to determine the effect of two stressors of flight, altitude-induced hypoxia and aircraft noise, and to examine the contributions of fatigue and clinical experience on cognitive and physiological performance of CCATT providers. This repeated measures 2 x 2 x 4 factorial study included a sample of 60 military nurses. The participants completed a simulated patient care scenario under aircraft cabin noise and altitude conditions. Cognitive performance was measured with Critical Care Scores, Critical Care Errors and Omissions, and Critical Care Reaction Times during the scenario. Physiological performance was measured four times during the scenario via vital signs and oxygen saturation. Differences in cognitive and physiological performance were analyzed using RM ANOVA. A multiple regression model was developed to determine the independent contribution of fatigue and clinical experience to cognitive and physiological performance as a function of altitude and noise. Critical Care Scores ($p = .020$) and Errors and Omissions ($p = .047$) were negatively impacted by aircraft cabin noise. Noise resulted in increase in respiratory rate ($p = .019$). Critical Care Scores ($p < .001$) and Errors and Omissions ($p = .002$) worsened with altitude. Heart rate ($p < .001$) and respiratory rate ($p < .001$) increased with altitude, and oxygen saturation ($p < .001$) decreased. A regression analysis of Critical Care Reaction Time to First Defibrillation with altitude, noise, fatigue, current critical care experience, and experience accounted for 20% of the variance in reaction time ($p = .028$).

The care of critically ill patients is significantly affected by aircraft cabin noise and altitude. Noise and altitude largely act independently of each other. Safety and quality of care may be positively impacted with training and equipment better designed to assist in monitoring and assessment during aeromedical transport.

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Critical Care Performance in a Simulated Military Aircraft Cabin Environment

by
Margaret Mary McNeill

Dissertation submitted to the faculty of the Graduate School
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CHAPTER I: PROBLEM, BACKGROUND AND SIGNIFICANCE

Introduction

Since the start of Operation Enduring Freedom in October 2001, over 42,063 patients have been transported by the United States Air Force (USAF) aeromedical evacuation (AE) system: 5,000 missions have been flown with patients requiring critical monitoring and care. In April 2007 alone, the service flew 1,046 patients, including 146 critically ill patients, from the war zones (2007). After Operation Desert Storm in 1991, new doctrine established that *stabilized*, versus stable patients, are transported out of the theater of operation earlier in the course of their illness and recovery. These stabilized patients tend to be critically ill and vulnerable, and often require complicated care. This new philosophy in AE dictated the formation of Critical Care Air Transport Teams (CCATTs), a trio of critical care clinicians (registered nurse, physician, and respiratory therapy technician), to provide specialized care aboard military aircraft during transit until the patients can be admitted to treatment facilities capable of providing definitive care. The environment of care during AE is unique compared to a hospital-based intensive care unit, or even the austere critical care environment of a deployable medical system treatment facility, such as an Air Force Expeditionary Medical System (EMEDS) or an Army Combat Support Hospital. Many environmental factors, known collectively as the stressors of flight, impact the work performance of the CCATT members during AE. These stressors include altitude-induced hypoxia, noise, vibration, decreased humidity, acceleration, temperature, gravitational forces, and fatigue. Human factors science, or ergonomics, has been applied rigorously to the design of the aircrew environment and human-machine interface to overcome the stressors of flight in the cockpit and ensure optimal and safe performance. In contrast, although the CCATT members are subject to the same stressors of flight, the cabin environment and medical equipment have not been engineered to reflect or compensate for the environmental impacts on work performance when caring for patients.

Problem Statement

Research has shown the impact of the flight stressors on the aircrew, but there has been no research on how flight stressors impact cognitive and physiological performance of CCATT members during AE missions. There is little doubt that performance of the CCATT members will directly impact patient outcomes.

Purpose of the Study

The purpose of this quantitative study was to determine the impact of altitude-induced hypoxia and aircraft noise, and the contributions of fatigue and clinical experience on cognitive and physiological performance during critical care delivery. The long term goal is to improve performance of critical nursing care delivery during aeromedical transport; thereby positively impacting patient safety and outcomes. The study of work performance in the AE environment will improve care, ensure patient safety, impact operational readiness, training and policy, and inform AE medical equipment design.

Research Questions

1. What are the effects of military aircraft noise and altitude-induced hypoxia on cognitive and physiological performance of CCATT personnel during a simulated critical care patient scenario?

2. What are the effects of fatigue and clinical experience on cognitive and physiological performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia?

Background and Significance

The core of the Air Force Medical Service (AFMS) mission is to care for the injured and wounded. The proposed research will improve the capability of the Air Force to accomplish this mission. According to Lieutenant General Taylor, former USAF Surgeon General, as stated in his 2005 Congressional testimony, two very important ways in which medics contribute to the fight include enhancing human performance and providing care to casualties. In 2004, over 28,000 patient movements took place in the AE system (Department of Defense Office of the Inspector General, 2005). Hundreds of these patient movements involved patients who were in critical or guarded status, requiring intravenous fluids, pain medication, mechanical ventilation or cardiac monitoring. The Air Force is now transporting stabilized warfighters to a higher level of care in the early critical hours of their illness or injury, when they are very vulnerable to rapid changes in condition (Taylor, 2005). The CCATT medical teams care for critically ill patients as they are moved out of the theater of war to Germany or the U.S. aboard military fixed-wing aircraft, such as the C-130 Hercules, C-17 Globemaster, C-21, KC-135, KC-10, and C-5 Galaxy. The letter-number designation indicates the type of military aircraft. The C-130, C-17, and C-5 are designed to transport cargo. The C-21 is a Lear jet used for personnel travel, and the KC-135 is a tanker, designed for aircraft refueling. The aircraft most often used for transporting critically ill patients on longer transcontinental flights from Europe back to the U.S. has been the C-141 (DuFour, 2003). Beginning in 2006 the C-17 Globemaster became be the primary aircraft used for long distance transport between Iraq and Germany, and Germany and the US. The C-17 was developed for the Air Force to efficiently transport very large amounts of military cargo. The cabins of military aircraft have few amenities or design elements that blunt the effects of the stressors of flight. Comfortable passenger seating, insulation, and fine temperature control are among the design elements that make commercial aircraft travel more tolerable for passengers and crew.

According to Lieutenant General Taylor, the AFMS is seeking to enhance human performance for our troops through cutting edge research and development that will improve the both the safety and performance of our troops in the expeditionary Air Force (Taylor, 2005). The CCATTs are a force multiplier, a factor that dramatically increases or multiplies the combat-effectiveness of a given military force. This research will contribute to our understanding of human performance, specifically critical care skills by CCATT teams working in the AE environment, and whether interventions to improve quality of critical care in the air are requisite for optimal performance.

Altitude-induced Hypoxia

At sea level the air column above earth exerts a force approximately equivalent to the weight of a column of mercury (Hg) 760 millimeters (29.9 inches) high. This height of mercury, placed in a barometer, counterbalances the normal sea level pressure of Earth, 1 ATA, or 1 bar (1000 millibars). As one ascends in altitude, the weight of air exerting pressure decreases, and atmospheric pressure falls almost exponentially (Piantadosi, 2002). Air composition remains constant, at 21% oxygen, 78% nitrogen, and 1% other gases (including carbon dioxide at 0.03%, argon, neon, helium, krypton, hydrogen, and xenon in trace amounts) no matter the altitude (Darwish, 2003; Harding, 2002). It is the partial pressure of oxygen that falls, due to the decrease in pressure on the oxygen molecules in the atmosphere at altitude. The number of oxygen molecules decreases in proportion to the drop in barometric pressure.

At sea level where the barometric pressure is 760 mm Hg, the partial pressure of oxygen (PO_2) is 160 mm Hg, equal to 21% of the total:

$$PO_2 = .21 \text{ X } 760 \text{ mm Hg} = 160 \text{ mm Hg}$$

When the total barometric pressure drops as altitude increases, the partial pressure of oxygen will still be 21% of the total. The PO_2 goes down because the total pressure decreases. This is explained by Dalton's Law of Partial Pressures, which states that the total pressure of a volume of gas is equal to the sum of all the partial pressures of the gases in the mixture (Piantadosi, 2002).

The actual pressure of oxygen that is inspired is actually lower than 160 mm Hg at sea level, because it is humidified as it passes through the airways, and the partial pressure of water vapor at body temperature is 47 mm Hg (Levitzky, 2003). This amount needs to be considered when calculating the oxygen being inspired, as it is part of the air entering the trachea. In order to obtain the partial pressure of oxygen that is inspired, this water vapor partial pressure must be subtracted from the total barometric pressure:

$$PO_2 = .21 \text{ x } (760 \text{ mm Hg} - 47 \text{ mm Hg}) = 150 \text{ mm Hg}$$

To obtain the partial pressure of alveolar oxygen (PA_{O2}) the following formula applies:

$$PAO_2 = .21 \text{ X } (760 \text{ mm Hg} - 47 \text{ mm Hg}) - PACO_2 / R$$

$PACO_2$ is the partial pressure of the alveolar carbon dioxide and R is the respiratory exchange ratio. At sea level, the alveolar oxygen pressure equals 103 mm Hg. Because of the efficiency of gas exchange in the lungs, this is very close to the arterial oxygen pressure (PaO_2). PaO_2 pressure is a commonly obtained laboratory value in arterial blood gas measurements. Table 1 includes the measures of the various pulmonary gases at different altitude levels (USAF School of Aerospace Medicine, 2005a).

Table 1

Pulmonary Gases at Altitude when breathing air
As the barometric pressure decreases with altitude, the pressure of oxygen available for inspiration and subsequently in the alveoli, decreases. As ventilation increases to compensate for this drop in oxygen, pressure of carbon dioxide in the alveoli decreases, and the respiratory exchange ratio rises (USAF School of Aerospace Medicine, 2005a).

Altitude (feet)	Barometric Pressure mm Hg	Tracheal Inspired PO_2 mm Hg	Alveolar PO_2 mm Hg	Alveolar PCO_2 mm Hg	Respiratory Exchange Ratio
Sea Level	760	149	103	40	.85
5,000	632	123	80	38	.87
10,000	523	100	61	36	.90
15,000	429	80	46	33	.95
18,000	380	70	38	31	.98
20,000	350	64	34	30	1.00
22,000	321	57	30	28	1.05

At an altitude of 8,000 feet, the barometric pressure is 565 mm Hg. Multiplying by the fraction of oxygen (the FiO_2 is still 21%) in the total gives a partial pressure of oxygen of 118 mm Hg. A partial pressure of 118 mm Hg is equivalent to approximately 15% of the ambient oxygen available at sea level (Darwish, 2003). Subtracting water vapor partial pressure from the atmospheric pressure at 8,000 feet results in an inspired partial pressure of oxygen of 109 mm Hg (Samuels, 2004).

$$PO_2 = .21 \text{ X } (565 \text{ mm Hg} - 47 \text{ mm Hg}) = 109 \text{ mm Hg}$$

The PO_2 of 109mm Hg will result in a PaO_2 of approximately 53-64 mm Hg and an arterial oxygen saturation (SaO_2) of 85-91% (Darwish, 2003).

Cells cannot exchange the gases in the lung directly. A delivery and exchange system manages the following functions: movement of gases between the ambient air and the lungs; matching of ventilation with blood flow; diffusion between alveolar air and capillary blood; vascular transport between the lungs and the tissues; and diffusion between the capillary blood and the tissues (Fulco & Cymerman, 1988). Diffusion from high to low concentrations plays a large part in oxygenation of blood and tissues.

Relationship to Physiological Performance

With ascent to altitude, the total atmospheric pressure decreases, so the pressure of each gas decreases. A decrease in pressure of each gas translates into less oxygen molecules available for use by the tissues of the body. A decrease in partial pressure of oxygen explains why individuals experience hypoxia at altitude. Hypoxia is the absence of adequate supply of oxygen to the tissues. At a cabin altitude of 8,000 feet, the decrease in oxygen is not noticed by most individuals. People with cardiopulmonary diseases are susceptible to having medical problems under moderate and higher altitude conditions.

Boyle's Law predicts that as atmospheric pressure falls on ascent, there will be an inversely proportional increase in gas volumes. An increase in gas volume affects parts of the body where gas is trapped; the lungs, gastrointestinal tract, ears, and sinuses. Gas expansion with the drop in barometric pressure that occurs with ascension to altitude is why patients with a pneumothorax must have a chest tube in place for flight, because the pneumothorax will increase in size during ascent. Gas expansion with ascent also dictates that patients who have had abdominal surgery should have a nasogastric tube, to prevent unwanted distention. The volume of air in the endotracheal tube cuff will also increase, and the cuff pressure must be monitored and adjusted during flight, or the cuff filled with saline instead of air prior to flight. The effects of altitude not only impact patients; the CCATT personnel, the aircrew, and the other personnel in the aircraft cabin also experience the effects of the decrease in barometric pressure.

Increased pulmonary ventilation is the first change seen in the body at altitude, in an effort to increase the pressure of oxygen in the lungs. The decreased pressure of oxygen in the alveoli and arterial blood stimulates arterial chemoreceptors and an increase in alveolar ventilation. Increased alveolar ventilation occurs because as carbon dioxide is expired in excess during increased ventilation, the concentration of oxygen can increase. Dalton's Law of Partial Pressures explains these events, which states that the total pressure exerted by a mix of gases is equal to the pressure of each of the gases in the mixture. The increase in ventilation is mainly achieved by increasing the tidal volume of each breath. This increase in volume and depth of breathing limits the drop in alveolar oxygen pressure (Fulco & Cymerman, 1988).

The human body compensates for increased hypoxemia with cardiovascular responses that maintain oxygen delivery by increasing blood flow, and redistribution of it to the organs with the greatest need for oxygen, the heart and brain (Piantadosi, 2002). Oxygen delivery is regulated by a complex set of receptor mechanisms and autoregulation. The chemoreceptors are chemosensitive cells responsive to oxygen deprivation, carbon dioxide excess, and hydrogen ion excess. Chemoreceptors located in the chemoreceptive carotid and aortic bodies, along with the pressure sensitive baroreceptors, excite nerve fibers transmitting to the vasomotor center of the brain stem (Guyton & Hall, 2006). The stimulation of the vasomotor center increases blood pressure back to normal in a low pressure state, in order to increase blood flow for oxygen delivery, and elimination carbon dioxide and hydrogen ions.

At altitudes up to 2,500 meters, or 8,000 feet, the increase seen in alveolar ventilation is matched by an increase in pulmonary perfusion to the apices, the poorly perfused areas of the lungs. Increased alveolar ventilation increases the surface area available for gas exchange. The response is due to an increase in pulmonary artery pressure (Fulco & Cymerman, 1988).

Baroreceptors are nerve endings that lie in the walls of many arteries that respond when stretched. Major locations for the baroreceptors are the carotid sinuses and the aortic arch. Low pressure will cause the baroreceptors to stimulate the circulatory system to increase cardiac output and increase vasoconstriction, resulting in an increase in blood pressure, which will maintain blood and oxygen delivery to tissues (Guyton & Hall, 2006).

During rest and submaximal exercise under conditions of acute hypoxia, cardiac output increases via an increase in heart rate (as opposed to stroke volume), so that oxygen uptake is maintained at sea level amounts. Sympathetic stimulation of the cardiac beta-adrenergic receptors is the likely mechanism (Fulco & Cymerman, 1988).

Decreased oxygen also acts on the chemoreceptors to regulate respiration via nerve transmission to the respiratory center of the brain. Excess carbon dioxide or excess hydrogen ions in the blood mostly act directly on the respiratory center itself, which results in an increase in the strength of the inspiratory and expiratory motor signals to the muscles of respiration. Carbon dioxide elevations are the main stimulus for the respiratory center in the brain to increase respiration, because hydrogen ions do not as readily cross the blood-brain barrier (Guyton & Hall, 2006). When the body has a normal amount of carbon dioxide in the blood, oxygen will stimulate the brain to increase respirations when the chemoreceptors detect a PaO_2 in the blood below about 70 mm Hg.

After oxygen diffuses into the blood in the pulmonary system, it is carried to the tissues. A very small amount of oxygen is dissolved in the plasma, and the majority of oxygen is carried in combination with hemoglobin. The oxygen-hemoglobin dissociation curve, seen in Figure 1, demonstrates a progressive increase in the percentage of hemoglobin bound with oxygen as PO_2 in the blood increases. The normal arterial oxygen saturation is approximately 97 percent (Guyton & Hall, 2006). Acute exposure to hypoxia causes a shift of the oxygen-hemoglobin dissociation curve to the right. With a shift to the right, oxygen is released more readily by the hemoglobin to the tissues, where it is needed. The more hypoxia, the more of a right shift occurs (Fulco & Cymerman, 1988).

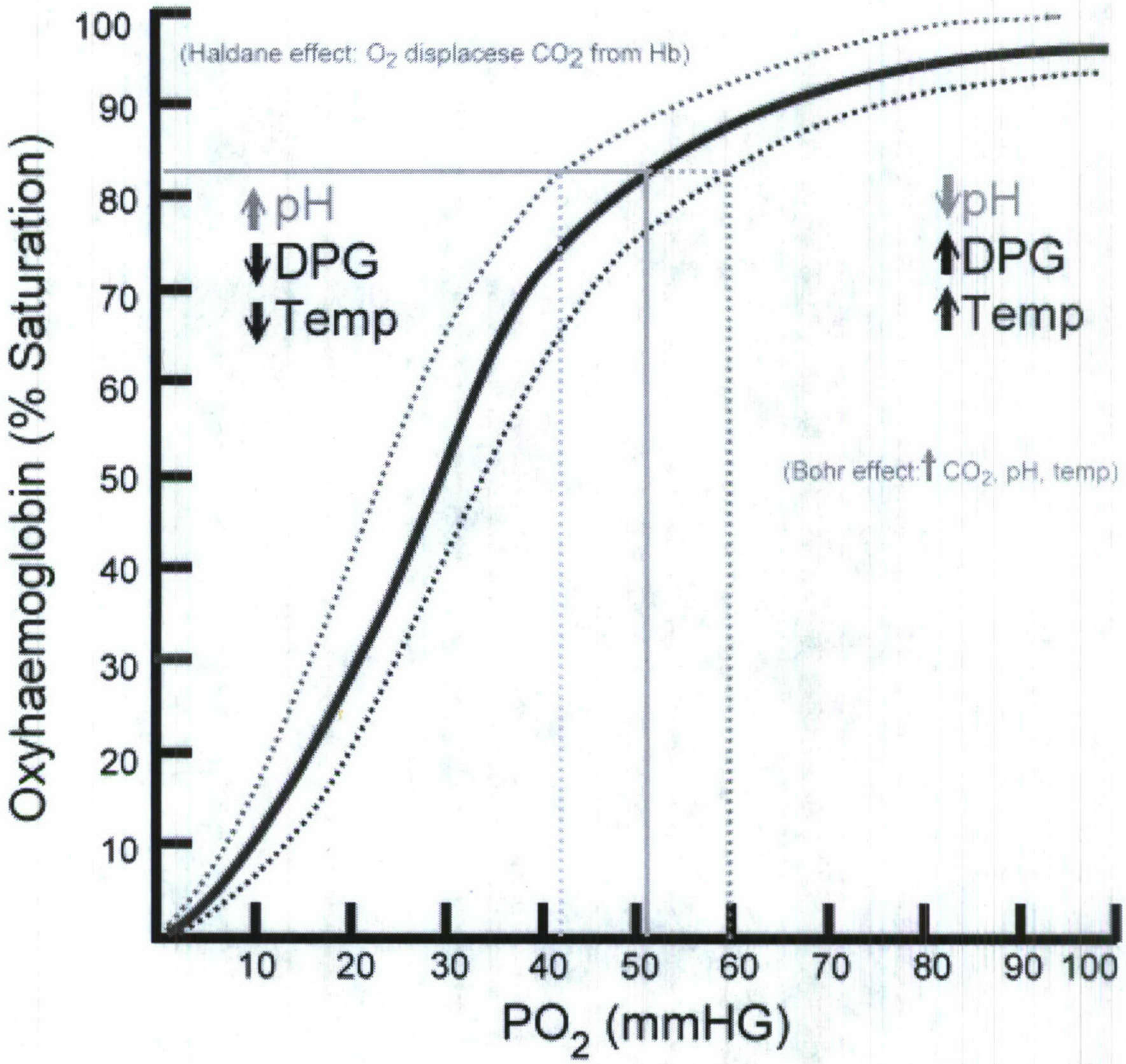

Figure 1. The oxygen-hemoglobin dissociation curve (www.answers.com, 2007)

In hypoxic conditions that last longer than a few hours, the quantity of 2, 3 DPG (also known as BPG) in the blood increases considerably, and this also causes a shift of the curve to the right (Guyton & Hall, 2006). Increased 2, 3 DPG however, decreases oxyhemoglobin affinity, decreasing the binding of oxygen to hemoglobin in the pulmonary system. Up to about 12,000 feet in altitude, there is a net benefit in oxygen delivery due to the increase in DPG. At higher altitude, the effects in the lungs actually create a disadvantageous balance between the improved off-load to the tissues due to the right shift, and the decreased binding related to 2, 3, DPG (Fulco & Cymerman, 1988).

Relationship to Cognitive Performance

The normal brain comprises two percent of the body's weight, but it requires approximately 20 percent of the total oxygen that is uploaded in the lungs and delivered by the blood supply and heart. The function of the brain can be partially understood by considering physiology at the cellular level. Cells in the central nervous system, neurons, provide the mechanism for information processing. The membrane of the neuron allows ions and other materials to pass in and out of the cells. Active transport processes of the cells pump ions across the membrane, creating the potential for electrical potential differences in and outside the cell. Differences in electrical potential across cell membranes are the basic prerequisite for the generation for transmission of impulses along a nerve. Chemicals, known as neurotransmitters, are released at the ends of the neurons and these signal to the next nerve cell, and impulse transmission continues along the nerve (Gazzaniga, Ivry, & Mangun, 2002). Many diseases, drugs, and conditions can affect cell function and neurotransmission, including hypoxia.

A constant flow of blood to the brain is required because the needed constituents for cellular energy production, glucose and oxygen, cannot be stored by brain cells. Two sets of arteries bring blood to the brain; the vertebral artery supplying the caudal sections, and the internal carotid artery which supplies the rostral sections. Blood flow to the brain is tightly coupled with the metabolic demand of the local nerve cells. Increase in activity of the neurons results in greater blood flow. Greater blood flow serves to deliver more oxygen and glucose, and more importantly, to carry away the waste products of increased to cellular activity (Gazzaniga, Ivry, & Mangun, 2002). Neuronal excitability is depressed by a lack or decrease in oxygen supply to the brain (Guyton & Hall, 2006). Because neuron activity is closely intertwined with cognitive performance, changes in oxygen delivery to the cells that impact activity can be observed in changes in performance.

Blood flow to each individual segment of the brain changes as much as 100 to 150 percent within seconds, in response to local neuronal activity. The type of activity being performed is related to different areas of the brain. Reading a book will cause an increase in blood flow to the visual areas of the occipital cortex and the language perception areas of the temporal cortex (Guyton & Hall, 2006).

One of the most important effects of hypoxia is decreased mental proficiency, with decreased judgment, memory, and performance of discrete motor movements. At high altitudes, the symptoms of hypoxia include sleepiness, laziness, a false sense of well-being, impaired judgment, blunted pain perception, increasing error on simple tasks, decreased visual acuity, clumsiness, and tremors. Severe hypoxia occurring at higher altitudes results in unconsciousness and death (Levitzky, 2003). Multiple studies have looked at the effect of hypoxia induced by altitude on both cognitive and physiological performance. It has been clearly demonstrated that at altitudes above 12,000 feet, human performance suffers (Blaber, Hartley, & Pretorius, 2003; Kida & Imai, 1993; Mackintosh, Thomas, Olive, Chesner, & Knight, 1988). However, the altitude where cognitive performance *begins* to be affected is unknown.

Cognition encompasses numerous mental processes, including perception and encoding, selective attention and orienting, learning and memory, language, control of action, and emotions. Studies on cognitive performance showed the effect of altitude of 5,000 to 12,000 feet when difficult tasks and those with *high* memory load (at least four pieces of information) are performed (Bartholomew et al., 1999; Kelman & Crow, 1969). Learning a new orientation task was affected at altitude as low as 5,000 feet (Denison, Ledwith, & Poulton, 1966). Such cognitive conditions are present when persons are providing care to critically injured patients (Potter et al., 2005).

There is a very limited availability of objective measures of performance, specifically for use in dynamic, operationally realistic environments (Tennant, 2003). Cognitive performance in the aviation community has been measured in two ways; with a full-scale simulator, or by substituting abstract tests that are thought to measure the same skills important for piloting an aircraft. The second strategy is the predominant one that appears in the literature. Test that have been used include those of simple reaction times, code substitution tasks, and vigilance assessment. Arithmetic tests have also been popular. One of the problems with these tests is that while they accurately measure the cognitive performance of an individual, these tasks are not the same as flying a plane. Another issue is that these tests are not as complex as the decisions a pilot must make in real life complex situations. Human performance metrics for individual performance include time to detect, time to recognize, and time to diagnose. These metrics are not measurable, but reaction or response time, or time to task or treatment, can be objectively measured, and reflects all three, along with the action selected to treat the problem. In general, performance is analyzable in terms of measures of response speed, accuracy, task accuracy while wearing protective equipment (earplugs), errors, sustained performance accuracy over time (Teichner & Olson, 1971; Tennant, 2003). Thinking in a medical emergency also requires speed and accuracy.

The use of simulation to evaluate healthcare performance is emerging in the literature much more frequently. Benefits of medical simulation include the fact that actual patients are not harmed, errors in diagnosis and treatment are allowed in training, and can be detected readily, allows for realistic preparation from basic to rare conditions, identical scenarios can be repeated, and team interaction can be practiced (Tennant, 2003).

Measuring healthcare performance, or any performance that has cognition as a major component, is problematic. Indirect and systems level outcome measures such as mortality, or costs are frequently measured. Outcomes on a unit, hospital, or national level can be very informative, and are used as measures of performance, but tell little about an individual's performance, or how it is impacted by the work environment.

Clinical environments are dynamic, complex, and inherently stressful. Nurses must manage increasingly complicated patients, and sophisticated technology, often with declining resources (Bucknall, 2003). This is certainly true of all healthcare practice, which becomes even more of a challenge in an austere military environment. Expert nursing practice requires complex thinking processes such as making inferences and synthesizing information to choose a course of action, along with psychomotor and effective skills (Higuchi & Donald, 2002). Potter et al. (2005) conducted a study that combined human factors engineering and qualitative data collection to compile a rich database for analyzing the nature of a nurse's cognitive work and the potential influence of environmental factors. The cognitive pathway they developed reveals the complexity of nursing practice (Potter et al., 2005). Cognitive performance under high cognitive load has been shown to be more sensitive to the effects of hypoxia in aviation research, but healthcare delivery in aircraft at altitude has not been studied.

Implications

This research evaluated the effects of altitude-induced hypoxia on the physiological and cognitive performance of CCATT members. Cognitive performance of the CCATT members is critical to the delivery of quality care to the seriously injured and critical ill casualty. The unstable and tentative nature of the patients being transported requires constant vigilance and cognition of the highest order. The effects of altitude-induced hypoxia on the clinician are important to determine because the performance of the clinician will affect the outcomes of the patients. Interventions to maximize performance and care delivery in light of the AE environment can be developed.

Noise

Another stressor of flight that has been found to effect work performance is noise. Sound is propagated through media which possess mass and elasticity, by the successive collision of molecules (Jones, 1983, p. 61). A wave is produced which can be described in terms of amplitude and frequency. Changes in frequency, measured in hertz, are heard as changes in pitch, while changes in amplitude are heard as differences in loudness (Jones, 1983).

Noise has at least three meanings; a sound which one does not want to hear, a sound varying randomly and aperiodically in intensity and frequency, and a sound which interferes with the reception of another (i.e. masks it) (Smith & Jones, 1992). Noise interferes with our perception of sound by either inducing hearing loss, or by masking the detection of a wanted sound (Jones, 1983). Clearly the sound made by the aircraft engine and transmitted to the cabin, which makes auditory patient assessments and equipment alarm detection difficult at best, and impossible in most situations, is noise.

Sound pressure (intensity) is measured with an instrument called a sound level meter. This instrument is a microphone attached to an amplifier which then drives a read-out device. Commercially available sound meters measure overall sound level, a weighted average of all frequencies, and some have the capability to allow analysis of frequency, which is useful in engineering applications (Jones, 1983; USAF School of Aerospace Medicine, 2005b).

The unit of measure of the intensity of noise is the decibel (dB). Frequency of the noise, measured in terms of Hertz, represents the number of peaks of pressure per second.

> Sound level meters allow differential attenuation of the frequency range. This is important because the ear is not equally sensitive to all frequencies and three weighting networks can be used to simulate the action of the ear. The A-weighted network was chosen to simulate the sensitivity of the ear at low intensities, the B-weighted network was intended for medium intensities, and the C-weighted network for higher intensities. The A- and

C-weighted networks are more likely used, with the C-weighted network giving equal weight to all frequencies, and the A-weighting giving greater weight to the frequencies which contribute more to the effects on people (Smith & Jones, 1992, p. 3).

Using A-weighted measures of noise is the standard procedure for measurement of compliance with Occupational Safety and Health Administration and USAF workplace noise regulations (USAF School of Aerospace Medicine, 2005b).

The duration of is also a component of noise, with impulse noises being of short duration, and impact noises being longer and having a thud-like quality. Intermittent noise switches on and off, and this switching can be in a regular or irregular pattern, which can influence the effects of the noise (Smith & Jones, 1992).

Any performance task involving auditory information is likely to be impaired by the presence of noise. There is good general agreement on the effects of noise on hearing and the masking of auditory information. The non-auditory effects of noise on performance are less clear (Smith & Jones, 1992, p. 3).

According to Smith and Jones (1992) the effects of noise on performance depend on the type of task but also on task parameters and other features of the experimental situation. Adverse effects of noise are more likely to appear when attention to several sources of signals are required (Jones, 1983). There is clear evidence that noise may produce changes in performance in three possible ways:

1) noise leads to the choice of certain strategies in preference to others
2) noise reinforces the use of the dominant strategy

3) noise reduces the efficiency of the control processes which track and change performance

The effect of noise on performance shows a wide variance in results on individuals (Jones, 1983). Response to noise varies with perceptions of it, beliefs and attitudes toward it, and perceived degree of control over the noise source (Smith & Jones, 1992). After-effects of loud noise have been seen in experiments where the task was proofreading. The performance during the loud noise was unaffected by noise, but after the noise was stopped and further cognitive testing continued, the effects of noise surfaced. This effect was eliminated when the subjects were told prior to the exposure to noise that they could turn it off at any time (Glass & Singer, 1972).

High noise levels increase errors (Mathews, Davies, Westerman, & Stammers, 2000). In a study in an industrial setting, noise tended to increase error rates associated with talks of high cognitive loads or with a high degree of control precision, to reduce errors with physical strength, and to have no effect on errors associated with manual dexterity (Levy-Leboyer, 1989).

Experimental studies of noise are usually artificial in that they examine the effects in isolation. In real life, the person is often exposed to a complex combination of stressors and it is important to determine whether the different factors have additive, interactive, or independent effects (Smith & Jones, 1992, p. 19). There is limited information from field research that supports a relationship between noise levels, errors, and accidents (Melamed, Fried, & Froom, 2004; Smith & Jones, 1992).

Noise may impair performance when task demands are particularly high, or when resources are depleted due to other factors such as fatigue or anxiety. The decline in accuracy of serial reaction as time progresses is perhaps the most reliable of this category of noise effects (Mathews, Davies, Westerman, & Stammers, 2000, p. 192).

Airplane cabin noise varies depending on the type of plane, and is usually between 95 and 105 dB. Gasaway summarized noise levels in the cockpits of 528 fixed wing aircraft, finding the average level to be 95 dB (Gassaway, 1986). Passengers seated in the back of the plane may experience higher noise levels, and engine noise during take-off may approach 115 dB (Deafness Research Foundation, 2006). The average sound level in the cabin during C-17 flight is 86 dB as measured by the Air Force Research Laboratory Battlefield Acoustics Branch (F. Mobley, personal communication, March 20, 2007). Similar levels were measured in a C-17 by the Royal Air Force of Great Britain (Noise and Vibration Division, 2005). For reference, normal conversation has a sound level of 50-60 dB(A), a chainsaw about 115-120 dB(A) (Eurocontrol, 2006). At 79-80 dB, the level of noise in the cabin of a commercial airliner, normal conversation is not audible more than 5 feet away, and conversations across the aisle will not be audible. At 84 dB, communication at more than 3 feet requires shouting. This is the sound level in many factories, and sound levels above this require hearing protection. At sound levels above 90 dB speech is not possible (USAF School of Aerospace Medicine, 2005). It is standard practice to wear earplugs to abate the effects of noise during AE. Importantly, noise during CCATT missions can interfere with assessments and patient care.

Implications

There has been no research on the effects of noise on performance of critical care delivery. In addition to the direct effects of noise on the CCATT provider, noise also makes it difficult to assess patients and to hear equipment alarms. This research seeks to add to the knowledge of this stressor of flight and its influence on the CCATT provider. This has implications for the outcomes of the critically ill casualties transported over long distances in military aircraft.

Fatigue

The nature of the work of the CCATT – caring for severely injured patients over long hours in an extremely inhospitable environment of hypoxia, vibration, low humidity, low temperatures, and high noise levels – is thought to escalate fatigue. These stressors of flight, transcontinental missions, disrupted sleep patterns, and changing time zones, along with the demands of caring for the critically ill, together serve to increase energy expenditure and delay restorative sleep or rest. The contribution of fatigue to performance in this environment is important to understand, as it will affect the outcomes of the critically ill patients.

Several studies have concluded that sleep deprivation and fatigue are related to deficits in performance of clinicians (Gaba & Howard, 2002; Veasy, Rosen, Barzansky, Rosen, & Owens, 2002; Weinger & Ancoli-Israel, 2002). Serious medical errors were related to extended work hours in a study of care provided in intensive care units (Landrigan et al., 2004). Noise is also thought to contribute to fatigue. Listening through static to more than one channel in the noisy environment of the typical cockpit or flight deck is one of the determinants of how soon a crew becomes so fatigued that the mission or safety is affected (USAF School of Aerospace Medicine, 2005b). Fatigue can be measured objectively through performance measures such as reaction time or number of errors (DeVries, Michielsen, & VanHeck, 2003). It can also be measured with subjective instruments. Altitude and sleep deprivation have been shown to interact, and this interaction was enhanced by increasing workload (Mertens & Collins, 1986).

Experience

Clinical experience has been shown to have an impact on performance as measured by mortality, in a study by Tourangeau, Giovannetti, Tu and Wood (2002). More years of experience on a clinical unit were predictive of lower 30-day mortality. Priority setting and decision-making have been linked to experience in nurses (Banning, 2007; Hendry & Walker, 2004). Experience has been shown to be a factor in expedient treatment of respiratory failure with continuous positive airway pressure therapy, resulting in improved outcomes (MacGeorge & Nelson, 2003). There are fewer opportunities to practice in a busy critical care environment in Air Force Treatment facilities, and length and type of experience may impact outcomes of patients transported by CCATTs.

Summary

In summary, thousands of casualties are transported via the AE system in the military, with up to 10% requiring critical care in transit. The provision of care to critically ill patients is complex. Warfighters that are stabilized during the first hours after devastating injuries and then loaded on a military cargo aircraft for a six to ten hour flight, require top quality critical care due to the extremely tentative nature of their conditions. The critical care providers may be impacted by the environmental stressors of aircraft noise and cabin altitude of 8,000 feet. Hypobaric pressure changes and altitude-induced hypoxia affect oxygenation of tissues, and have been shown to affect complex cognitive functions. Noise has been shown to also have an affect on performance. Noise affects the ability of the CCATT providers to assess their patients. Research has focused on the effects of altitude above 12,000 feet on cognitive performance in pilots. The effects of lower altitudes (6,000 – 10,000) feet on cognitive performance, particularly under conditions of high memory load, have not been well described. The cabin altitude of military aircraft is typically 8,000 feet. The impact of the combination of the stressors of flight in a military aircraft environment on the CCATT provider who delivers care to critically ill patients is not understood and has never been examined. The contributions of fatigue and experience on the delivery of care in the AE environment have also not been explored.

CHAPTER II: REVIEW OF THE LITERATURE AND CONCEPTUAL FRAMEWORK

Review of the Literature

There has been much research on the performance of aviators and the impact of the variables of altitude, age, medications, exercise, and workload on performance of tasks similar to those required during the piloting of aircraft. Conducting research is not feasible during actual work performance because of the safety implications; therefore the aircraft environmental factors and pilot work have been simulated. It is standard practice in this aviation research to simulate the cognitive and physical aspects of pilot work, and to use instruments that are assumed to measure the same cognitive processes or physical workload as used while piloting an aircraft. The literature in this area of research spans several decades. Included in this chapter is a review of the research that has been done on noise and performance at altitude. The chapter also includes discussion of the conceptual framework, and conceptual definitions.

The studies of mountain climbing and the effects of long-term exposure to very high altitudes above 18,000 feet, while reviewed, have not been included. The conditions of the military aircraft cabin environment are substantially different than these high altitudes, and the physiological adaptation of acclimatization that occurs with the long-term exposure does not occur in the population and circumstances of interest.

Many of the publications reviewed give altitudes in meters instead of feet. Table 2 gives a list of equivalent meters and feet at altitude.

Table 2

Altitude in feet and meters

Feet Altitude	Meters altitude
2,000	610
3,000	914
4,000	1,219
5,000	1,524
6,000	1,829
7,000	2,134
8,000	2,438
9,000	2,743
10,000	3,048
12,000	3,660
15,000	4,572
20,000	6,096

Altitude and Performance

Several researchers have examined the effect of moderate altitude on performance. Fiorica, Burr, and Moses (1971) conducted a study with 40 male subjects between the ages of 19 and 30 years, who were randomly assigned to one of four experimental groups. They compared performance with a vigilance test at ground level and at a simulated altitude of 11,500 feet, with and without 100 percent supplemental oxygen. The vigilance test was administered in four consecutive one-hour sessions with a 10 minute rest period between each. They also examined physiological parameters of arousal, heart rate and internal temperature, which they theorized are a component of vigilance. In addition, physiological variables associated with hypoxia were studied. This study did not yield statistically significant differences in the vigilance test or physiological variables in the four conditions, but the authors believed that the experimental conditions did not adequately impose the vigilance or physical work demands of real situations (Fiorica, Burr, & Moses, 1971). The results also cannot be generalized beyond young males, which are not the population demographic in the pilot community today, nor the nursing population.

In a study by Pavlicek et al. (2005) cognitive and emotional processing in non-acclimated subjects during short-term exposure to hypobaric hypoxia of moderate and high altitude levels was examined. The researchers were particularly interested in assessing the behavioral changes that have been described by mountaineers, such as elevated mood and loss of inhibition. End-tidal carbon dioxide and blood pressure significantly changed in the 4,500 meter altitude session. Blood pressure and arterial oxygen saturation correlated at 4,500 meters, indicating central hypoxia. These findings are likely reflective of a hypoxia-induced functional impairment of the vasomotor center, part of the autonomic nervous system adaptation to hypoxia at high altitudes. However, no statistically significant differences were seen in the neuropsychological tests at the different altitude profiles. Measurable effects of altitude in the parameters of frontal lobe-mediated cognitive function were also not detected (Pavlicek et al., 2005).

The purpose of another study was to investigate the effect of orthostasis (induced by the head-up-tilt method) and altitude (3,660 meters, equal to 12,000 feet) on the interaction of cerebrovascular, respiratory, and cardiovascular control and its relation to presyncope in healthy subjects (Blaber, Hartley, & Pretorius, 2003). Changes in cardiovascular control due to environmental or pathological reasons can be seen with an orthostatic stress such as the head-up tilt (HUT). The major finding was that ventilatory interaction with cerebrovascular control played a statistically significant role in rate of onset of presyncope at altitude; those subjects with lower resting mean cerebral blood flow velocity and end-tidal carbon dioxide, and higher carbon dioxide reactivity, had significantly lower orthostatic tolerance at altitude. Also, at altitude there was an observed withdrawal of parasympathetic activity and a blunted sympathetic response to the HUT and this may have been exacerbated by the interaction of hypoxia and hypocapnia on cardiovascular control (Blaber, Hartley, & Pretorius, 2003). This was a small study with only 14 subjects, but the methods and results revealed interesting physiological changes.

Kida and Imai (1993) studied the effects of hypobaric hypoxia on cognitive processing by recording event-related potentials (ERPs) in a go/no-go reaction time paradigm under various simulated altitudes. The altitudes the subjects were exposed to in a hypobaric chamber were sea level, 3,000 meters (10,000 feet), 4,000 meters, 5,000 meters, and 6,000 meters. The dependent variables included reaction time (RT), electroencephalogram (EEG) activity, arterial oxygen saturation, heart rate, respiratory rate, and symptoms of hypoxia. Thirty-nine healthy right-handed males ages 22-40 participated. EEG activity was recorded as subjects performed a RT test at each altitude. RTs significantly increased at high altitudes of 4,000 meters or more. Those that had RT changes also had changes in latency and amplitude of these EEG parameters (Kida & Imai, 1993).

Bartholomew et al. (1999) examined the effect of moderate altitude on short-term memory using three groups of participants: one group tested at 15,000 feet, one at 12,500 feet, and a control group tested at 2,000 feet. Short-term memory was tested by a 30-minute vigilance test, half the responses giving a high memory load, half giving a low memory load. Seventy-two volunteers, 59 men and 13 women, participated in one of the largest studies on altitude and performance found in the literature. The results showed a statistically significant negative effect of altitude on ability of subjects to recall read-backs during high memory load. This indicates that altitude may influence the amount of cognitive resources available to process information (Bartholomew et al., 1999).

Nesthus, Rush, & Wreggit (1997) examined the physiological and subjective responses, as well as the simulated flight performance, of general aviation pilots during a cross-country flight scenario. Ten pilots of a mild hypoxia group were compared with 10 pilots of a control group (17 males, 3 females). Measurements of flight performance were gathered during a 3-day, 2 hour per day, cross-country flight scenario, after an initial training/sea level day. The subjects breathed oxygen mixtures or compressed air to simulate the various altitudes. Simulated altitudes of sea level, 8,000 feet, 10,000 feet, and 12,500 feet were experienced by the participants. The ceiling on flying without oxygen for pilots is 12,500 feet. Flight performance was measured from the Basic General Aviation Research Simulator (BGARS), along with adherence to procedures and error rates. The physiological parameters measured were partial pressures of oxygen and carbon dioxide, heart rate, and arterial oxygen saturation. The physiological parameters provided statistically significant results between the two pilot groups and the four altitude conditions. There were significantly more procedural errors committed by the hypoxia group during cruise flight at 10,000 feet. Significantly more procedural errors also occurred during the descent and approach phases of flight from 10,000 feet on day three and during descent from 12,500 on day four (Nesthus, Rush, & Wreggit, 1997).

In a study by Kelman and Crow (1969), mental performance operationalized by scores on vigilance task was measured in 80 medical students (53 male, 27 female) that were randomly assigned to two groups. To determine if a selected test of cognitive performance would be impacted by altitudes of 8,000 feet, the experimental group was compared to a control group at 2,000 feet. The levels of vigilance required for the tests were also varied between high and low. With the more difficult task the subjects' initial performance was significantly decreased in hypoxic conditions compared to the control group. Familiarity with the test resulted in no difference. The researchers concluded that their work corroborates other studies that support that learning is more difficult at altitude (Kelman & Crow, 1969).

To determine if psychomotor performance and visual reaction time were affected by acute exposure to mild or moderate hypoxia, Li et al. (2000) tested 18 healthy male volunteers at various simulated altitudes. The altitudes of 300 meters (control), 2,800 meters, 3,600 meters, and 4,400 meters were simulated in a hypobaric chamber for one hour. The cognitive tests of finger-tapping, simple reaction time (SRT) and 4-choice reaction time (CRT) were completed. At 3,600 meters the CRT showed statistically significant decrease in performance, and the statistically significant decrease was larger at 4,400 meters. Finger tapping and SRT showed no changes. There was no measurable impairment of visual reaction time and psychomotor performance at an altitude of 2,800 meters, but psychomotor performance was effected at 3,600 meters and higher (Li et al., 2000).

Wu, Li, Han, Wang, and Wei (1998) observed the effects of acute moderate hypoxia on human performance of arithmetic. Sixteen healthy young male subjects were exposed to various simulated altitudes in a hypobaric chamber in random order, and subjects and researchers were blinded to the altitude. Performance was compared between 300 meters (control), 3,600 meters (approximately 12,000 feet), 4,400 meters, and 5,000 meters. Error rate of the continuous calculation test and reaction time of the addition-subtraction test increased significantly after one hour exposure to 3,600 meters. Reaction time, total number completed, and performance of all tests decreased after exposure to 5,000 meters for 30 minutes (Wu, Li, Han, Wang, & Wei, 1998).

To examine the effects of a prolonged exposure to mild hypoxia on performance and endocrine reactivity, Vaernes, Owe, and Myking (1984) tested seven subjects (6 male, 1 female) at a simulated altitude of 3,048 meters (10,000 feet). Neuropsychological tests of motor function; tremor, hand grip strength, finger tapping speed; and cognitive tests of arithmetic, reasoning, perceptual speed, and visual reaction time, were completed at arrival to the altitude at 3 minutes and each second hour afterwards, up to 6.5 hours, along with blood endocrine analysis. Performance tests indicated that there was a statistically significant effect of mild hypoxia during the 6.5 hour exposure. However, there were few linear relationships between impairment and duration of exposure. A statistically significant relationship was found for short-term memory and reaction time. There was minor impairment in arm muscle speed. The neuropsychological tests and subjective symptoms showed performance decrements due to mild hypoxia. Dizziness, headache, feelings of weakness were the main complaints by the participants (Vaernes, Owe, & Myking, 1984).

Blogg and Gennser (2006) studied the effects of 15% and 10% oxygen inhalation on medial cerebral artery blood flow velocity and psychomotor performance, in a repeated measures design study with 21% oxygen as the control. The tests measured reaction time, spatial orientation, voluntary repetitive movement, and fine manipulation. In this study psychomotor tests were significantly different only at the 10% oxygen levels, and the cerebral blood flow increased with performance of the tests at normal oxygen levels and remained unchanged during hypoxia (Blogg & Gennser, 2006).

Summary

Cognitive and physiological performance at altitude have been studied by several researchers. There is no doubt that high altitude levels above 15,000 feet have a negative effect on physiological and cognitive function. Under conditions of high cognitive demand, Kelman and Crow (1969) and Bartholomew et al. (1999) found a decrease in performance as measured by neurocognitive tests at altitudes from 8,000 to 12,500 feet. Fiorca, Burr, and Moses (1971) , Pavlicek et al. (2005), and Blogg and Gennser (2006) found no significant differences in neurocognitive measures at conditions equivalent to moderate altitudes of 8,000 to 15,000 feet. Kida and Imai (1993), Blaber, Hartley, and Pretorius (2003), Li et al. (2000), and Wu et al. (1998) found neurocognitive performance changes at conditions equivalent to altitudes of 12,000 to 13,500 feet. Changes in physiological performance were observed above 12,000 feet by Blaber, Hartley, and Pretorius (2003), and above 13,500 feet by Kida and Imai (1993). In summary, the altitude and conditions where cognitive and physiological performance begins to suffer is not known. There is evidence that performance of work of high cognitive demand is affected at lower altitude conditions.

Altitude, Exercise and Performance

Several studies combined altitude and exercise to see if the interaction would affect performance. Denison, Ledwith and Poulton (1966) completed two experiments with the purpose to explore performance at low altitudes, as seen in a pressurized aircraft cabin. In the first experiment, the altitudes tested were ground level and 8,000 feet. Eight men were tested at altitude and ground level on the two tasks, four in one order, and four in the other. The subjects did mild exercise to simulate physical pilot workload, and performance was measured on an orientation task with choice and reaction times. In Experiment 2, the altitude levels were 8,000 feet, 5,000 feet, and ground level. Twenty-eight men were divided into 3 groups. One group tested at 8,000 feet, then ground level; the control received these in reverse order; and the third group tested at 5,000 feet and ground level. The two conditions were tested in the same session for each experiment. Ergometry set at moderate levels to simulate pilot workload, and an orientation task were performed simultaneously. From the results, the researchers concluded that mild hypoxia significantly affected performance while the task was being learned, but not after practice. This study was the first demonstration of performance decrements at an altitude as low as 5,000 feet. The researchers surmised it was because the measurements they used were more sensitive to performance differences under hypoxia. They concluded novel tasks, such as emergencies, may be effected by altitudes as low as 5,000 feet (Denison, Ledwith, & Poulton, 1966).

One study was designed to investigate whether acute exposure to moderate simulated altitude levels could modify heart rate variability (HRV) during exercise. HRV is indicative of the autonomic nervous system activity, thought to play a role in adaptation of the body to altitude. The altitudes tested were 500 meters, 1,500 meters, 2,500 meters, and 3,500 meters (approximately 12,500 feet). Seven healthy men completed one resting measurement in the upright sitting position and two submaximal steady-state cycle ergometry tests at 25% and 50% of their estimated maximum work rates. The experiments were conducted in random order within 2 hours at the various altitudes in a hypobaric chamber, and the ascent to the different altitudes was separated by 2 hours. Acute effects of altitude exposure on HRV were only found during exercise at moderate altitude (greater than 2,500 meters). The findings point to an increase in sympathetic nervous system indicators with a decrease in parasympathetic nervous system indicators under these conditions (Yamamoto, Hoshikawa, & Miyashita, 1996).

Higgins et al. (1982) studied 12 healthy young men in each of four conditions involving two altitudes during testing (ground or 12,500 feet), and two exercise conditions administered prior to testing. Their purpose was to explore the effects of prior strenuous physical exertion during subsequent mild hypoxia, examining possible interaction with performance of flight-related tasks over a two and a half hour period. Subjects were randomly assigned to complete one hour of heavy exercise or no exercise before performance testing. Physiological parameters of heart rate and norepinephrine excretion were also measured. Each four-hour session was separated by at least a day. Altitude was simulated by administration of gas mixtures equivalent to altitude conditions through a mask. The overall composite Multiple Task Performance Battery (MTPB) score at 12,500 feet was significantly lower than at ground level. Exercise was associated with a statistically significant increase in heart rate, increased norepinephrine levels, and some better MTPB scores. Heart rate was also significantly higher at altitude (Higgins et al., 1982).

The purpose of a study by Paul and Fraser (1994) was to determine if the ability of naïve subjects to learn new tasks was affected by exposure to a range of mild acute hypoxic exposures in an altitude chamber, and to assess whether light exercise modifies arterial oxygen saturation and performance at these altitudes. The altitudes tested were 5,000 feet, 8,000 feet, 10,000 feet, 12,000 feet, and ground level for a control. Cognitive performance, as measured by spatial orientation, logical reasoning, and serial choice reaction time, and testing along with physiological performance, as measured by respiratory rate, end-tidal carbon dioxide and pressure of oxygen in arterial blood, and arterial oxygen saturation, were tested. Participants were 144 young (aged 19-25 years) volunteers from the Canadian Forces, who were randomly assigned to 16 groups divided equally among the four test altitudes. Of the four groups allocated for each altitude, two were tested at exercise and the other two at rest. Of the two exercising groups, one was assessed at altitude first, and then ground level. The other group had the opposite order.

Of the rest group, order was handled similarly. All three tasks were performed by each subject in each condition of ground and altitude. No statistically significant differences were found between the corresponding four blocks of the first session in resting and exercising subjects tested at ground level before altitude compared to altitude before ground. Serial choice reaction time was faster in resting versus exercising subjects. The ability to learn new tasks was not impaired by mild hypoxia in this study (Paul & Fraser, 1994).

Hudgins (1997) completed a study with 14 subjects (6 males, 8 females) tested at ground and hypobaric chamber simulated altitudes of 8,000, 10,000, 12,500, and 15,000 feet. The purpose of the study was to examine the relationships between five different altitude exposures and cognitive performance, and to examine the possible effects of physical activity at each altitude on cognitive performance. The Synwork1, a computerized performance test of simultaneous tasks, was administered before and during altitude exposure, and during submaximal exercise (40% maximum oxygen consumption or 40%VO_2max) at altitude. Five testing sessions took place on separate days, at separate altitudes, selected in random order, and blinded. There were statistically significant differences in cognitive performance in arithmetic errors and correct arithmetic responses of the Synwork1 between ground level and all altitude conditions. Exercise and altitude also produced statistically significant results but this may be confounded by the distraction of doing the exercise (Hudgins, 1997).

The effects of hypoxia on the regulation of blood pressure are not well understood. The purpose of a study by Knudtzon (1989) was to investigate the short term effects of hypobaric hypoxia on blood pressure, and to measure different vasoactive substances during maximum exercise at different simulated altitudes in a decompression chamber. The altitude conditions were sea level, 2,450 meters, 3,700 meters, and 4,600 meters. The exercise conditions were rest, submaximum exercise for 10 minutes, and maximum exercise for 10 minutes.

Ten healthy females performed exercise on a cycle ergometer in an altitude chamber. The sessions consisted of 10 minutes of rest at the given simulated altitude, submaximal exercise for 10 minutes, followed by maximal exercise for 10 minutes. A minimum of two days of rest separated each session. Blood levels of pH, pressure of oxygen, pressure of carbon dioxide, total lactate, aldosterone, plasma rennin, neuropeptid-Y, vasoactive intestinal peptide, angiotensin converting enzyme, epinephrine, and norepinephrine were drawn after each exercise condition, and 20 minutes after the maximal exercise period. The study showed a significantly lower elevation in systolic blood pressure during maximal exercise at increasing hypoxia. The vasoactive substances did not significantly change in any of the experimental conditions. The reason for reduced blood pressure responses at hypoxia have not been determined (Knudtzon et al., 1989).

Miles and Schaefer (1988) hypothesized that the pulmonary pressure response induced by hypoxia might magnify fluid influx into the lung interstitium. The purpose of this study was to describe acute changes in pulmonary function and volumes induced by running in a simulated normobaric and hypoxic environment. Cardiac output was measured with impedence cardiography. Thoracic fluid shift was measured with segmental transthoracic impedence. Eleven men ran five miles under normoxic and hypoxic conditions. A PO_2 Aerobic Exerciser was used to approximate altitude of 2286 meters (about 7,000 ft). The lung volume changes after each run were due to expiratory limitation. Changes in fluid in the lungs did not occur as hypothesized (Miles & Schaefer, 1988).

Because the effects of high altitude on maximum oxygen consumption (VO_2 max) are known, Squires and Buskirk (1982) explored the effects of low levels of altitude on aerobic capacity. Twelve young men performed six treadmill graded tests in a hypobaric chamber. Test 1 and 6 were at ground level, test 2 was at 914 meters, test 3 was at 1219 meters, test 4 was at 1524 meters, and test 5 was at 2286 meters. The order of testing was randomized and blinded. Performance as measured by VO_2max was significantly lower than control by 4.8, 6.9, 11.9% at altitudes of 1219, 1524, and 2286 meters respectively. Maximum arterial oxygen saturation (SaO_2max) also significantly decreased in a similar fashion. VO_2max in physically well-conditioned persons was significantly reduced during acute exposure to 1219 meters and above (Squires & Buskirk, 1982).

The purpose of the study by Terry (2001) was to evaluate potential differences in actual and perceived cognitive performance at moderate altitude (10,000 feet and 14,000 feet) versus ground level (control) under several conditions. Ten subjects were exposed to each altitude condition on separate days and asked to perform a computer test, SYNWIN, while at rest at ground level (5,000 feet [this was in Colorado]), at rest at altitude, after 10 min of exercise at altitude, and while breathing supplemental oxygen at altitude. Before and after each test at altitude, subjects were asked to provide pre- and post-test estimates regarding their performance. Actual performance on the test was significantly greater at 10,000 feet compared to both ground and 14,000 feet while at rest. Performance at 10,000 feet was also significantly better than that at 14,000 feet after exercise and oxygen. Post-test scores were always significantly better, as was performance with supplemental oxygen. Subjects also could not accurately predict their own performance; they under-scored their performance after the resting and post-exercise conditions, and over-scored if they received oxygen (Terry, 2001).

Summary

In studies where the effects of altitude and exercise were examined, the results were inconsistent. Denison, Ledwith and Poulton (1966) found decreased performance at conditions as low as 5,000 feet. Hudgins (1997) observed negative effects at 8,000 feet. Terry (2001) observed better performance at 10,000 feet. Paul and Fraser (1994) found no differences.

Physiological performance at altitude with exercise was found to be affected as measured by VO_2max. VO_2max decreased with altitude (Squires & Buskirk, 1982). Elevations of systolic blood pressure in women that were exercising at altitude were not as high as at ground conditions. The causes and implications of these results are not fully understood.

Altitude, Medications, Alcohol, and Performance

Pearson and Neal (1970) investigated the interaction of drugs, alcohol, and hypoxia on performance of skilled operation functions. This 3 x 2 x 2 factorial design study looked at placebo, Librium, or meprobamate; alcohol or no alcohol; and altitude of 12,000 feet or ground level. Task performance was a vigilance test and the Welford serial performance test, indicators of monitoring and tracking. Nine male subjects rotated among three stations and performed the tasks. The method of assignment to testing conditions was a combination of random and prescribed techniques. Two days separated each session, and each subject tested under all conditions, so the total experiment took 12 days for each subject. Subjects reported to the clinic the evening before testing began to take the drug capsule, sleep, take another dose in the morning, and begin testing. Baselines on the tests were obtained, and then orange juice with or without alcohol was given, and then testing continued. Subjects were paid, and also performed under a bonus system where they were paid more for better performance and study completion. Task loads, subject training, and performance feedback operated jointly to mitigate potential decremental effects of drugs and hypoxia. There were no drug-alcohol effects on performance. There was also high individual variability. Pay for performance may have confounded the results (Pearson & Neal, 1970).

Valk, Van Roon, Simons, and Rikken (2004) completed a study to determine the effects of desloratadine, a long-acting, non-sedating antihistamine, on healthy subjects placed under conditions of simulated cabin pressure. In a double-blind cross-over study, 21 subjects (healthy males) randomly received single doses of desloratadine 5 mg, diphenhydramine 50 mg (active control), and placebo on different days separated by washout periods of 7 days, and were tested for performance at a simulated 8,000 feet altitude. Testing included pre-dose levels of alertness and fatigue, and post-dose levels at 1, 2, 3, 5, and 6 hours. Performance was measured by vigilance and tracking, multi-attribute task battery, Stanford Sleepiness Scale, and pulse oximetry. Desloratadine had no detrimental effects on sleepiness or performance. Diphenhydramine had statistically significant effects on tracking, and completion of tasks, as well as sleepiness (Valk, Van Roon, Simons, & Rikken, 2004).

Summary

Studies of the effects of alcohol and medication at altitude illustrate that the results vary with testing conditions, type of medication, and the individual. Results may depend on individual characteristics, such as tolerance to alcohol, and motivation to succeed or excel during testing.

Altitude, Age, Workload, and Performance

Mertens, Higgins, and McKenzie (1983) evaluated the utility of the Multiple Task Performance Battery (MTPB), which is comprised of flight-related tasks, as a tool for future for age-related research. It was expected that workload-induced performance decrements would increase with age and that performance might not differ between age groups in low-workload conditions. Forty-five subjects, 15 in each of 3 age groups were evaluated for normal health and intelligence. The age groups were 20-29, 40-49, and 60-69 years. Following 15 hours of training on the MTPB, three hours on each of five successive days, subjects performed in two 3-hr sessions, one a ground level and one at simulated altitude. The altitudes were sea level and 12,500 feet. Also completed in each session were a fatigue checklist, urine catecholamines, and heart rate. Order was reversed in half the subjects, and sessions separated by two days. The three hour sessions included intervals of different workloads. Increasing workload caused a statistically significant decrease in performance in all age groups. The amount of decrease increased significantly with age as well. Altitude did not effect performance, contrary to previous findings using the MTPB (Mertens, Higgins, & McKenzie, 1983).

Altitude, Age and Sleep Deprivation

To examine the potential interactions of age, sleep deprivation, and simulated altitude, Mertens and Collins (1986) studied 30 men; 16 of age 30-39 years, and 14 of age 60-69 years. The sleep variable was either a normal night's sleep, or loss of one night of sleep. The altitude variable was either ground level or 12,500 feet. Altitude was simulated by mixing 13.5% oxygen with 86.5% nitrogen; compressed air was used for the ground level condition; the gas mixtures were administered to the subjects through worn face masks. Participants were then tested on the MTPB in four sessions over a 2-week period that had at least two days between sessions. The four test conditions included the four possible combinations of the two altitudes and two sleep conditions. There was a statistically significant interaction of sleep deprivation and altitude that was enhanced by increased workload. When subjects were sleep-deprived, performance was affected in all conditions, but the most in the altitude condition. Decreased performance was noted with age, particularly with increased workload, but it did not interact with sleep deprivation. The MTPB tasks have high content and face validity for aviation, and are performed on a special console. (Mertens & Collins, 1986).

Noise and Performance

To examine the effect of aircraft noise on aircrew performance, Pierson (1971) recorded aircraft noise at 99 dB(A), and played it during tests of performance of perceptual judgment and intellectual judgment (number of errors and time on the McCloy test) at four and eight hours of exposure. Eight subjects were tested for conceptual and intellectual judgment ability during eight hours of simulated aircraft noise and eight hours of quiet, separated by a week. A split plot Latin square design was used. Two subjects dropped out with signs of distress during the noise session. Perceptual judgment was not affected by noise. Number of errors on the McCloy test significantly increased during the second four hours of the noise session (Pierson, 1971).

Harris and Johnson (1978) completed three experiments that manipulated conditions of time of exposure, type, frequency and decibels of noise, to determine the effects of infrasound (acoustic energy below 20HZ, found in jet aircraft) on cognitive performance. Twelve males in the first two experiments, and eight males and eight females in the last were tested in a Dynamic Pressure Chamber that generated the noise/sound. Cognitive performance was measured by a Serial Search Task in the first study, and Complex Counting Task in the second two studies. Infrasound at low levels did not adversely affect human performance, male or female, contrary to results reported in previous studies (Harris & Johnson, 1978).

A prospective experimental cross-over design study was conducted in a sleep laboratory to determine if acute exposures of healthy individuals to loud occupational noise during the daytime would cause changes in nocturnal sleep architecture, heart rate during sleep and cortisol levels. Ten healthy male subjects were exposed to a quiet (<45 dBA) or a loud (>75 dBA) work environment, and sleep patterns, heart rate and cortisol levels were measured. Nocturnal sleep architecture was disturbed in healthy subjects who were exposed to loud occupational noise during the day, and this may be related to stress, as manifested in a delayed cortisol response and a decrease in the fall of heart rate during sleep (Gitanjali & Ananth, 2003).

In a cohort observational study of nurses working in a pediatric intensive care unit, noise was shown to correlate with several measures of stress, including tachycardia and annoyance ratings. The average noise level was 61 dB(A), with a range of 43 to 122 dB(A) during the study (Morrison, Haas, Shaffner, Garrett, & Fackler, 2003).

To study effects of operating room noise, noise levels in operating rooms were measured, the sounds recorded, and then played back to anesthesia residents during testing of mental efficiency and short-term memory. The average noise level was 77.32 dB(A). The tests used were the Trail Making Test and Digit Symbol Test for mental efficiency and the Benton Visual Retention Test for short-term memory, and the researchers observed that operating room noise significantly reduced the performance of the residents (Murthy, Malhotra, Bala, & Raghunathan, 1995).

Summary

Noise has differing effects on individuals as measured in the studies reviewed. Harris and Johnson (1978) found no negative effects of noise on performance during neurocognitive testing. Pierson (1971) observed an increase in errors and had subjects drop out of his study with noise conditions of 99 dB(A) due to distress. Pediatric intensive care nurses had increases in heart rate and annoyance ratings with noise at work in the unit measured at levels up to 122 dB(A) (Morrison, Haas, Shaffner, Garrett, & Fackler, 2003). Cognitive performance was decreased in surgical residents with operating room noise played at 77 dB(A) (Murthy, Malhotra, Bala, & Raghunathan, 1995). Noise was shown to have affected sleep and heart rates after exposure (Gitanjali & Ananth, 2003).

Noise, Altitude and Performance

There was a substantially smaller body of literature on the effects of noise and altitude on performance. To assess the effect of altitude on speech intelligibility in aircraft noise, eight male subjects were fitted with an aviation headset with an audiometer, and in a double-blinded randomized order were tested at 0, 10,000, 13,000 and 16,000 feet in a hypobaric chamber. Results showed a statistically significant increase in speech intelligibility in aircraft noise with altitude. Wagstaff, Tvete, and Ludvigsen (1999) felt that their experiment better approximated operational environments where noise decreases with altitude, and this might explain their results. The researchers called for replication, and the mechanisms of the results are not understood (Wagstaff, Tvete, & Ludvigsen, 1999).

Slowing of reaction times has been observed with auditory stimuli. Fowler and Grant (2000) clarified the contradictory evidence of the effects of hypoxia on auditory thresholds. Six subjects (4 male/2 female) breathed both room air as a control, or low oxygen mixtures to maintain arterial oxygen saturations at 74%, and then audition was measured at frequencies between 500 and 4,000 Hz. The order of the two separate sessions was switched for half the subjects, and one day separated the testing sessions. Hypoxia produced a statistically significant but clinically in statistically significant decrease in thresholds of 1 dB across all frequencies tested. The decrease in reaction times seen with auditory stimuli may not be due to auditory changes, but central/cognitive mechanisms (Fowler & Grant, 2000).

To investigate the effects of 6.5 hour exposure to 85 dB(A) turboprop aircraft noise and an 8,000 feet simulated altitude on intellectual judgment, Pierson (1973) employed a split plot Latin square design. Six male subjects were tested at sea level/quiet conditions, then seven days elapsed and they were retested at altitude (altitude chamber) and noise. Twenty-four individual comparisons of control and noise-plus-hypoxia data were done, and of these, 11 revealed better scores under noise/hypoxia, 10 had poorer scores, and 3 had no change. The combination of noise/altitude did not significantly degrade performance as measured in this study (Pierson, 1973).

Summary

Fowler and Grant (2000) found a statistically significant but clinically insignificant decrease in auditory thresholds with hypoxia. Pierson (1973) found some participants performed better on neurocognitive tests with hypoxia and noise, and others had worse scores. Individual differences may contribute to performance at altitude with noise.

SYNOPSIS

The studies reviewed indicated high altitude conditions definitely caused decreases in cognitive and physical performance. The lowest altitude where performance is affected is unknown. Varying effects of low and moderate altitude on performance were seen. The type of cognitive task that is tested has been shown to have an impact on results. Tasks with high memory load tend to significantly and negatively effect performance in lower or moderate altitude conditions. Testing in conditions that more closely simulated actual operational conditions yielded statistically significant results at lower altitudes. The duration of time spent under the altitude conditions did not affect performance in the studies reviewed. The amount of time spent at the altitude before testing began varied from 3 minutes to 30 minutes, and data reviewed did not reveal trends. Many studies had small sample sizes, and power analysis was never discussed. This may have contributed to the differing results.

The influence of noise on performance is a less studied phenomenon. There were conflicting results within a study by Pierson (1973) that examined noise and altitude. The sample size was small and the number of comparisons made was numerous. This may have affected the statistical conclusion validity. A noise level of 99 dB(A), used in Pierson's earlier study, is slightly louder than most aircraft. In addition, earplugs for hearing protection were not used, limiting the generalizability of these results to CCATT missions (Pierson, 1971). The noise levels in the Gitanjali and Anath (2003) study may be more reflective of those in an aircraft cabin, but again ear plugs were not used. A few studies in healthcare environments showed noise had an impact on physiological and cognitive performance (Morrison, Haas, Shaffner, Garrett, & Fackler, 2003; Murthy, Malhotra, Bala, & Raghunathan, 1995). The major issue with noise in the aircraft cabin environment for AE could well be the difficulty in assessing patients without being able to hear above the noise and with the ear protection.

There have been no studies on healthcare performance in the conditions of the aircraft cabin. One study on aircrew perceptions of the commercial aircraft cabin environment revealed dissatisfaction with air quality (Lindgren, Norback, Andersson, & Dammstrom, 2000). Only one study focused on the provision of health care, and that was on the perceptions of helicopter crew on the influence of the environment on patient care capabilities. Performance of patient care was perceived to be more difficult during rotary wing air medical transport (Myers, Rodenberg, & Woodard, 1995).

There has been very little research on the combination of the stressors of flight and their effect on performance. The interaction of altitude-induced hypoxia with noise has an unknown effect on the provision of critical care. The other stressors of flight have also not been studied together in a realistic manner. The provision of critical care in the AE environment has also not been studied during actual missions. The predominant gender in the research has been males. All of these gaps may be avenues for future research.

CONCEPTUAL FRAMEWORK

The framework of factors affecting work performance as developed by Astrand, Rodahl, Dahl and Strome (2003) has its theoretical underpinnings in the discipline of work physiology. The main objective in work physiology is to enable working individuals to accomplish their tasks without undue fatigue, allowing for sufficient energy for enjoyment of leisure (Astrand, Rodahl, Dahl, & Stromme, 2003). These scientists capitalized on their expertise in nutrition, metabolism, environmental physiology, stress physiology, exercise and work physiology, and health, to shape the framework. The main focus of the framework is to guide the assessment of the effect of the total stress of work and the working environment on the worker. Figure 2 provides an illustration of the conceptual framework.

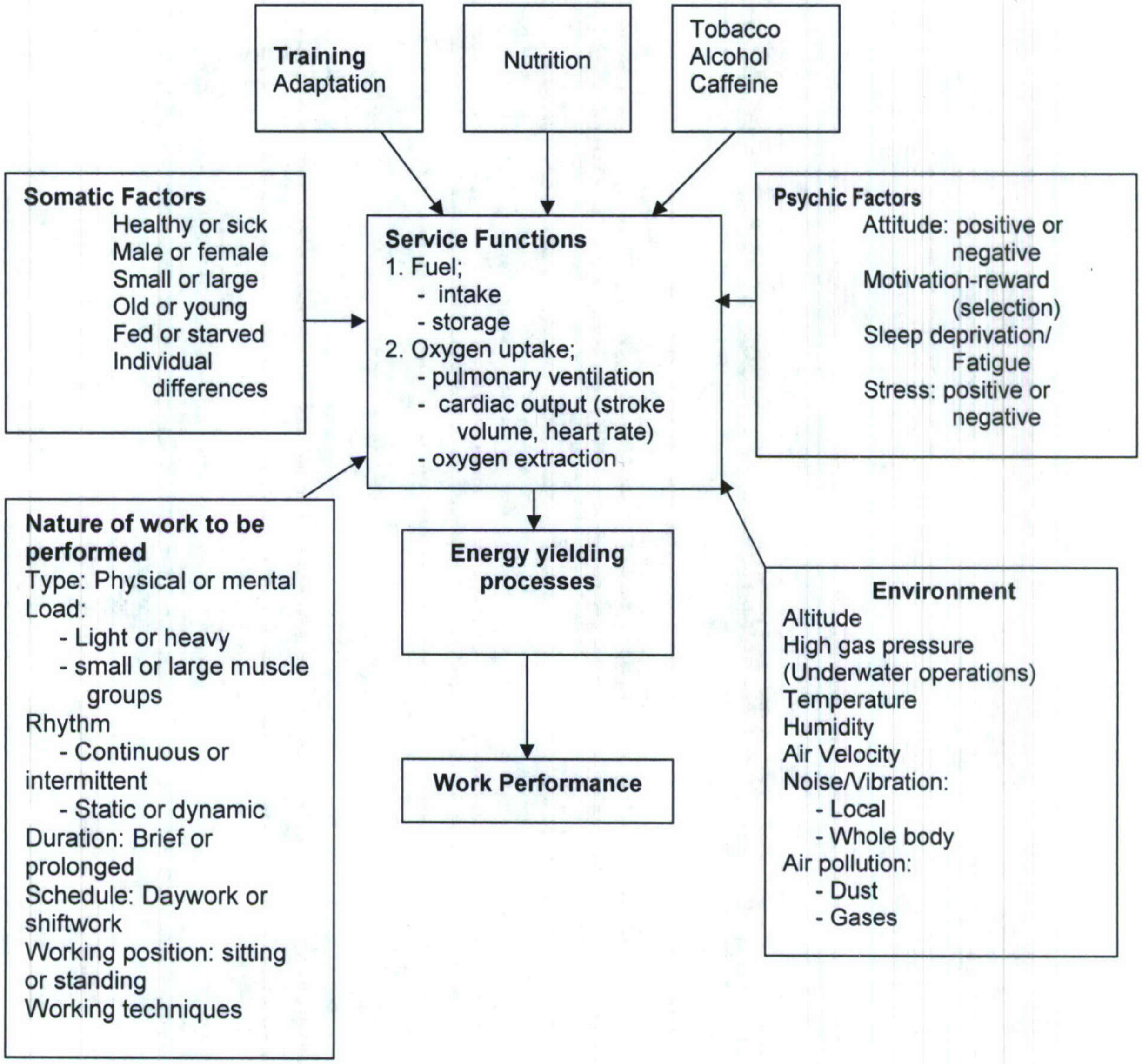

Figure 2. Factors Affecting Work Performance, from Astrand, Rodahl, Dahl, and Stromme, 2003.

The framework includes factors affecting work performance of an individual as controlled by energy yielding processes within the individual through the body's service functions of fuel regulation and oxygen uptake. Energy yielding processes are those that provide energy for the individual to perform. Energy yielding is the body transforming chemical energy into work. Energy yielding processes are physiological functions, including cellular respiration and circulation, taking place in the cells, tissues, organs, and body of an individual. A service function is one that allows the individual to perform. Service functions include fuel regulation and oxygen uptake, and effect organs and tissues of performance, such as the skeletal muscle or the brain. Fuel regulation is described as food intake, digestion, and handling of substrates at the cellular and tissue level. Fuel regulation strives to match the metabolism to the demands of the individual. Oxygen uptake is described as the process of the cells to extract oxygen from the blood. Oxygen uptake is dependent on the respiratory and circulatory systems, as well as nervous and hormonal mechanisms that regulate these functions.

The factors affecting work performance are divided into intrinsic and extrinsic factors. Intrinsic factors are characteristics or traits that are within the individual who is performing. Somatic factors, such as training and adaptation, nutrition, tobacco, alcohol, and caffeine, are intrinsic. Somatic factors affect the body, as opposed to the mind or spirit. Astrand and colleagues (2003) view health status, gender, age, nutritional state, and other individual differences, such as body dimensions or size as somatic characteristics. Training refers to repeated practice of a physical task. Training has been shown to improve performance (Astrand, Rodahl, Dahl, & Stromme, 2003). Adaptation is described as an alteration or adjustment in structure, habits, or function by which an individual improves his condition in relationship to his environment. An example of an adaptation to environmental conditions is an increase in hemoglobin seen in individuals living at high altitudes. Nutrition is described as the process by which a living organism assimilates food and uses it for energy, growth, and replacement of tissues. Tobacco, alcohol, and caffeine are inhaled or ingested substances that affect work performance through metabolic, respiratory, and other mechanisms. Tobacco has been shown to have a negative effect. Caffeine can have either a negative or positive effect on performance, and the effect of alcohol on individuals is dose dependent and can vary depending on tolerance and other factors (Astrand, Rodahl, Dahl, & Stromme, 2003). Psychic or psychological factors are intrinsic also. Psychic factors include motivation, attitude towards work, and the will to mobilize one's resources to accomplish a task.

Extrinsic factors occur outside the individual but affect the individual during performance. Extrinsic factors are those external to the individual that greatly influence performance, directly or indirectly. The nature of the work to be performed, and the environment, describe factors that are extrinsic. The nature of the work is important when considering the individual's capacity to endure work stress. The type of work, and the mental or physical load, will affect performance. Physical load can be described as the burden placed on the worker and reflects the muscle groups involved in physical work. Physical load can be categorized as light or heavy. Cognitive load can also be described as the mental burden placed on the worker, and refers to the total amount of mental activity imposed on working memory. Cognitive load can also be light or heavy. The rhythm of the work, whether continuous or intermittent, static or dynamic, affects performance. The ideal way to perform physical work is to perform it dynamically, with brief work periods interrupted by brief rest periods (Astrand, Rodahl, Dahl, & Stromme, 2003). The duration is described as the length of time of the work period. Duration has implications with fatigue, and impacts the service functions. Schedule, whether day or night, can also affect performance through a variety of mechanisms within the body. Position during work performance is important because standing is more stressful for the circulatory system, but sitting limits movement and muscle activity. Working technique is how the individual performs the work, and techniques affect individuals differently.

The environment affects performance through the service functions and energy yielding processes. Extremes of pressure in the environment, different than the conditions under which the body normally functions, impact performance. The pressure is below normal at altitude, and above normal during under water operations, and this has a negative affect on physiological functioning of the body. Temperature, either extreme hot or cold, can affect metabolism and other aspects of performance. For example, work in very cold temperatures requires protective equipment, which may be bulky or hamper performance in other ways. Humidity is the amount of water vapor in the air. High or low humidity can affect services functions which in turn affects performance. For example, very low humidity contributes to dehydration. Air velocity is the speed of air. Air velocity can affect performance if it is manifested as high winds, or as poor air circulation in a small closed space. Noise affects performance as it damages hearing and elevates heart rate and affects other physiological parameters that reduce performance (Astrand, Rodahl, Dahl, & Stromme, 2003). Vibration, or rapid uncontrollable back and forth movement, is also an environmental factor that influences performance. Air pollution distribution and gases affect performance directly by increasing airway resistance and therefore ventilation, and indirectly through causing ill health.

Astrand and colleagues (2003) indicated that many of the factors affect each other, but this is not depicted in their model. For example, training and adaptation affect psychic factors. Their model is a simple representation of a complicated interplay of many factors that influence work rate and work capacity.

FRAMEWORK IN THE PRESENT STUDY

The framework guiding this study is an adaptation of the one developed by Astrand, Rodahl, Dahl and Strome (2003). A figure depicting the concepts and variables as they apply to this study appears in Figure 3. The modification includes further development of the concept of work performance, distinguishing between physiological and cognitive performance. These aspects of performance were frequently reflected in the literature. See Figure 4 for methods used to measure work performance in the cognitive and human performance arenas (Tennant, 2003). The physiological variables measured in this study were heart rate, blood pressure, respiratory rate, and oxygen saturation. The cognitive variables measured were simulated critical care scenario score, reaction times, and error and omission rates. Selected tests from the Automated Neuropsychological Assessment Metrics (ANAM4) cognitive battery were administered. The tests are the Simple Reaction Time, 2-Choice Reaction Time, Code Substitution (Learning), Code Substitution (Delayed Memory), Mathematical Processing, and Logical Relations.

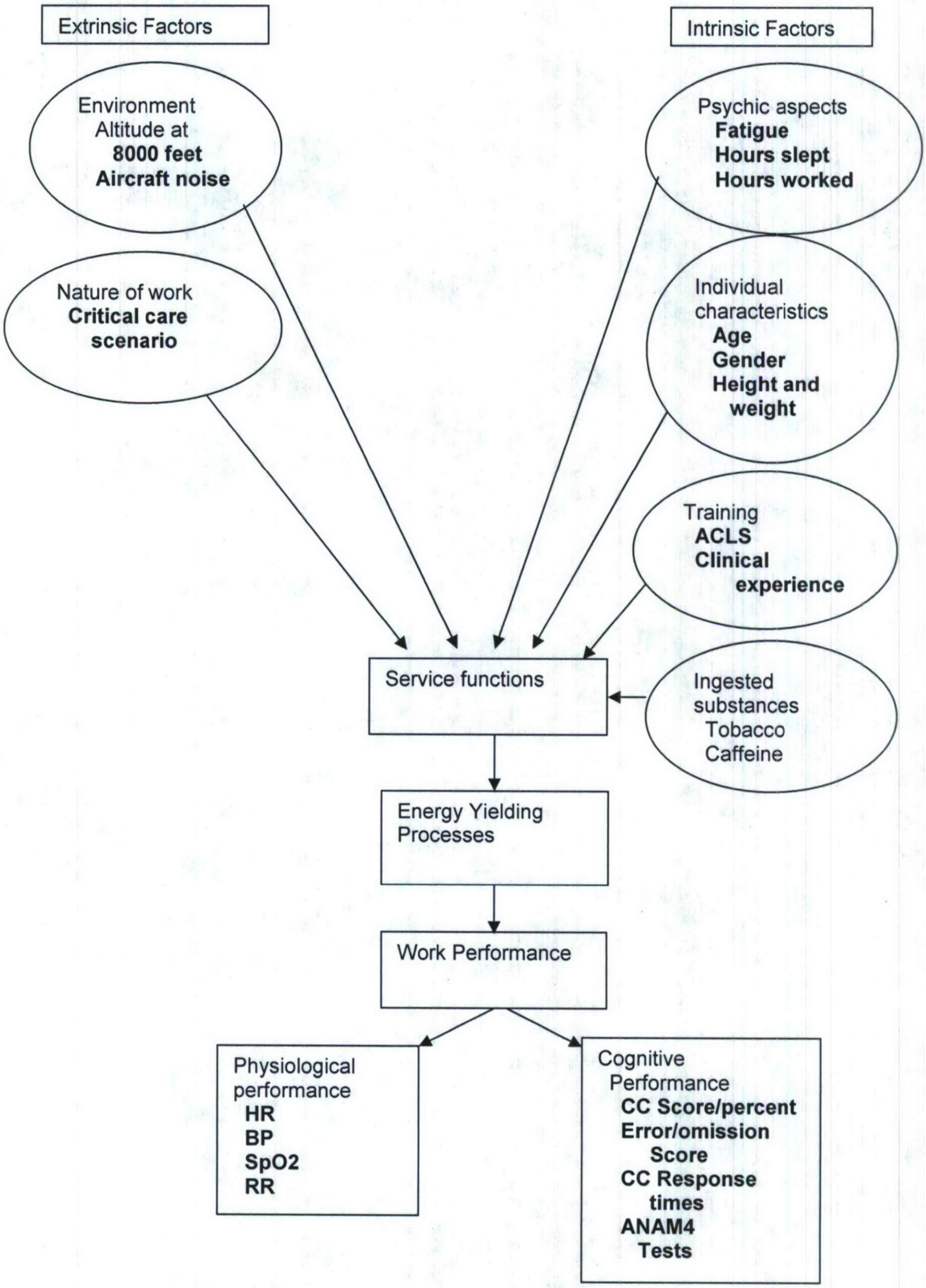
Extrinsic Factors
Intrinsic Factors
Environment Altitude at **8000 feet** **Aircraft noise**
Nature of work **Critical care scenario**
Psychic aspects **Fatigue** **Hours slept** **Hours worked**
Individual characteristics **Age** **Gender** **Height and weight**
Training **ACLS** **Clinical experience**
Ingested substances Tobacco Caffeine
Service functions
Energy Yielding Processes
Work Performance
Physiological performance **HR** **BP** **SpO2** **RR**
Cognitive Performance **CC Score/percent** **Error/omission Score** **CC Response times** **ANAM4 Tests**

Figure 3. Conceptual framework for the study: Factors affecting performance and the variables to be measured

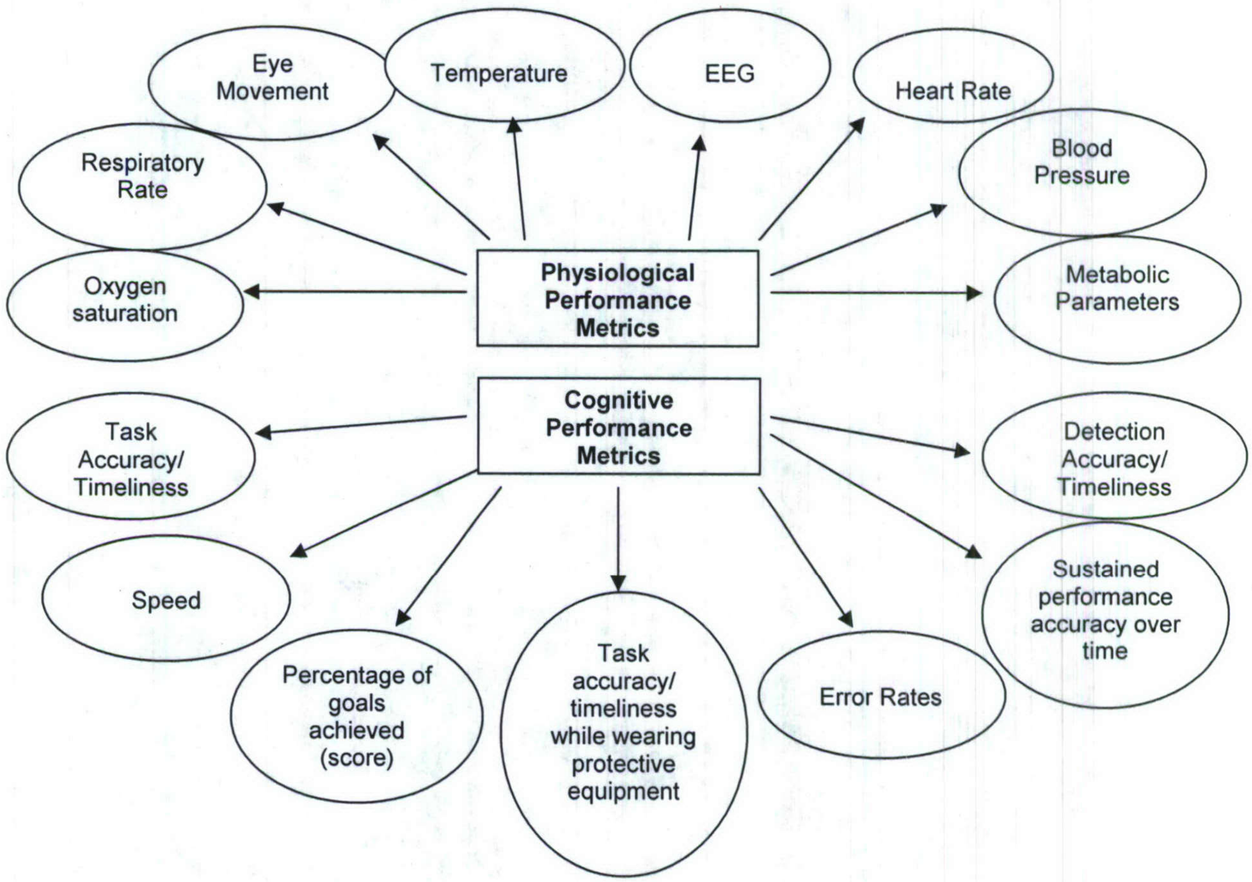

Figure 4. Outcome Measures of Cognitive and Physiological Performance. Adapted from Tennant, 2003.

Intrinsic factors examined in the study included the psychic factor of fatigue. Data on the individual characteristics of age, gender, height and weight were collected. The concept of training was expanded to include the concept of experience, and data on ACLS training were gathered. Information on caffeine and tobacco was also collected. The nature of the work performed in this study involved a cognitively complex critical care patient scenario. The main aspects of the environment of interest in this study were two of those that occur during aeromedical transport, altitude and noise.

CONCEPTUAL DEFINITIONS

Noise

Noise was conceptually defined as sound or a sound that is loud, unpleasant, unexpected, or undesired.

Military Aircraft Noise

Military aircraft noise was the sound experienced by individuals in the cabin aboard a C-17 military aircraft.

Ear Protection

Ear Protection was defined as Air Force approved earplugs for the reduction of sound audible to the outer ear. Ear protection is used by CCATT team members during flight.

Low Noise

Low noise was the sound experienced by the individuals in the simulation lab under normal operating conditions.

Altitude

Altitude was defined as height above sea level.

Cabin Altitude of 8,000 feet

A cabin altitude of 8,000 feet was the condition where a CCATT member cares for critically ill patients. This condition was simulated. A cabin altitude of 8,000 feet creates an environment equivalent to breathing in 15% oxygen versus the usual 21% (Darwish, 2003; Samuels, 2004). The decrease in the amount of oxygen inspired due to altitude is known as altitude-induced hypoxia.

Altitude-induced hypoxia

Altitude-induced hypoxia is the decrease in the amount of oxygen that is inspired by individual as a result of elevated altitude.

Ground Level Altitude

Ground level altitude was defined as the altitude at the University of Maryland School of Nursing in Baltimore, which is at sea level. In this study the participants breathed 21% oxygen through a mask, equivalent to breathing room air oxygen amounts at ground altitude.

Fatigue

The conceptual definition of fatigue is "the awareness of a decreased capacity for physical and/or mental activity due to an imbalance in the availability, utilization, and/or restoration of resources needed to perform activity" (Aaronson et al., 1999, p. 47).

Clinical Experience

Clinical experience was conceptually defined as the amount and type of clinical work done in the past by the participant.

Individual Characteristics and Demographics

Demographics were defined as the characteristics of the individuals in the sample, such as age, gender, race and ethnicity, education level, profession, years experience in nursing and the military, years critical care and/or emergency experience, and deployment experience (role, times, length, type of unit type code/position, number of patients transported).

Work

Work was defined as a job, manual labor, or mental pursuit (Astrand, Rodahl, Dahl, & Stromme, 2003).

Simulated Critical Care Patient Scenario

The simulated critical care patient scenario was conceptually defined as a cardiopulmonary arrest requiring resuscitation and stabilizing clinical interventions after clinical deterioration of the simulated patient.

Performance

Performance was conceptually defined as the process or manner of functioning or operating.

Cognitive Performance

Cognitive performance was the thinking and decision processes that one undertakes to perform a task or function. This can reflected in observed patient care activities, or other cognitive tests.

Physiological Performance

Physiological performance was defined as the function of the circulatory and respiratory systems.

CHAPTER III: RESEARCH DESIGN AND METHODS

INTRODUCTION

This quantitative study investigated the impact of altitude-induced hypoxia and military aircraft noise on cognitive and physiological performance during critical care delivery. Also examined were the contributions of fatigue and clinical experience to cognitive and physiological performance during critical care delivery. The long term goal is to improve performance of critical nursing care delivery during aeromedical transport, thereby positively impacting patient safety and outcomes.

Research Questions

1. What are the effects of military aircraft noise and altitude-induced hypoxia on cognitive and physiological performance of CCATT personnel during a simulated critical care patient scenario?

2. What are the effects of fatigue and clinical experience on cognitive and physiological performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia?

Operational Definitions

The main independent variables of interest in this study were altitude and noise, each of which had two levels. The first altitude level was that of the military aircraft cabin, 8,000 feet above sea level. The second altitude level was ground or zero feet above sea level. The first level of noise was the high level that occurs in the military aircraft, and the second level was the ambient sound level of the simulation lab during normal operations. Other variables of interest were fatigue and clinical experience. Information on participant characteristics and demographics were also collected.

The primary dependent variables of performance were categorized into cognitive and physiological measures. Cognitive performance was measured during the performance of critical care skills during two simulated scenarios, and with a computerized neurocognitive test battery (Lowe et al., 2007). The critical care scenarios involved one of the most challenging of critical care tasks, a cardiopulmonary resuscitation, to simulate the cognitive load of a real AE critical care mission. This ACLS testing scenario was a representation of a critical time sensitive patient scenario. Cognitive performance was measured by Critical Care Score, Critical Care Score Percent, Critical Care Reaction Times, Critical Care Error and Omission Score, and Throughputs for the neurocognitive test battery. Heart rate, blood pressure, respiratory rate, and oxygen saturation were the physiological outcome measures.

Independent Variables

Altitude

Altitude was operationally defined as the inhalation by the participant of a set percentage of oxygen as delivered by the Hypoxico 123 generator (Hypoxixo, New York) to simulate oxygen levels at either ground level altitude (21% oxygen) or 8,000 feet cabin altitude (15% oxygen).

Cabin Altitude of 8,000 feet

A cabin altitude of 8,000 feet was operationalized as the inhalation of 15% oxygen via mask connected to a Hypoxico 123 generator (Hypoxico, New York) with an in-line oxygen analyzer confirming the oxygen percentage, which created the condition of altitude-induced hypoxia.

Altitude of Ground Level

The University of Maryland School of Nursing is at sea level ground elevation, where the oxygen percentage equals 21%, and this level was the control condition for altitude. Air with an oxygen percentage of 21% delivered by the Hypoxico 123 generator, monitored by an in-line oxygen analyzer, was delivered through the mask to the participant.

Noise

Noise was operationally defined as the sound in the simulation lab measured in A-weighted decibels by an Extech Digital 407750 Sound Level Meter (Extech Instruments Corporation, Waltham, MA) positioned at the waist of the simulated patient.

Noise of the Aircraft Cabin

The operational definition of noise of the aircraft cabin was an 80 minute wave file equivalent to the sound aboard a C-17 flight during cruising altitude that was played for a total of 60 minutes at an A-weighted sound level of 86dB as measured by an Extech Digital 407750 Sound Level Meter (Extech Instruments Corporation, Waltham, MA) positioned at the waist of the simulated patient. The average sound level in the cabin during C-17 flight is 86 dB as measured by the Air Force Research Laboratory Battlefield Acoustics Branch (F. Mobley, personal communication, March 20, 2007).

The MicroTrack 24/96 played a wave file that was generated by Adobe Audition. This file was created by generating a pink noise spectrum and filtering it. Pink noise was used because it is defined as equal energy in each 1/3 octave band. This provided a flat spectrum. The signal was then filtered according to the measured spectrum so that the same shape was obtained. The M-Audio Microtrack 24/96 sound system recorder/player, pre-amplifier, and Crown amplifier generated the sound output. The file was amplified by the Crown amplifier and adjusted to register a reading of 86 dB A-weighted on the sound level meter. Bose sound system speakers were positioned ten feet from the location where the participants delivered the simulated care.

Ear Protection

Ear protection was operationally defined as the proper use, per the manufacturers' guidelines, of two E-A-R classic (NSN 6515-00-137-6345, Aearo Company, Indianapolis) foam earplugs during the sessions with noise. E-A-R classic foam earplugs that are approved for use during AE missions were given to participants to insert in each ear for ear protection. Prior to the noise sessions, the researcher supervised insertion of earplugs per manufacturer directions that accompanied the dispenser.

Noise of the Simulation Lab (No Aircraft Cabin Noise)

The ambient level of noise in the simulation lab was measured with the sound level meter during the study positioned at the waist of the simulated patient (Extech Digital Sound Level Meter 407750, Extech Instruments Corporation, Waltham, MA). The ambient noise was used as the no noise level of the sound variable.

Fatigue

Fatigue was operationally defined as the score on the self-report Fatigue Assessment Scale (FAS), a 10-item scale, with items that are reflective of both physical and mental fatigue (Michielsen, De Vries, Van Heck, Van de Vijver, & Sijtsma, 2004). The instrument can be found in Appendix 1. Items four and ten require reverse scoring, and the scale score is calculated by summing all items (Michielsen, De Vries, Van Heck, Van de Vijver, & Sijtsma, 2004).

In addition, information on hours worked during the day of the data collection, and hours slept during the previous 24 hours, and hours awake at the start of the testing session were collected.

Clinical Experience

Clinical experience for the participants in the study, all military registered nurses, was operationally defined as the total number of months of practice in a clinical setting. Practice included training. Data were also collected on the type of experience. Critical care and emergency settings were defined as a clinical setting where patients require complex assessment, high intensity therapies and interventions, and continuous nursing vigilance. Such settings include intensive-care units (ICUs); pediatric ICUs, neonatal ICUs, cardiac care units, cardiac catheter labs, telemetry units, progressive care units, emergency departments, and recovery rooms. This information was obtained on the demographic questionnaire (Appendix 2). Additional information was collected on military/deployment experience, and date of recent ACLS training. Information on currency of clinical practice, i.e. date last practiced in critical care or emergency setting, was also collected.

Participant Characteristics and Demographics

A demographic questionnaire was completed by the participants to obtain information on age, gender, race and ethnicity, education level, profession, years experience, months of critical care/emergency experience and/or other experience, and deployment experience (role, times, length, type of unit type code/position, number of patients transported) (Appendix 2). Smoking and caffeine can affect work performance and cardiovascular and respiratory functioning, and questions on the use of these substances were included in the Health Status/Inclusion and Exclusion Form (Appendix 3) (Astrand, Rodahl, Dahl, & Stromme, 2003).

Dependent Variables

Physiological Performance Variables

Physiological performance was operationally defined as the measures of heart rate, blood pressure, respiratory rate, and oxygen saturation as obtained by a Criticare 8100 EP (Criticare Systems, Inc., Waukesha, Wisconsin) monitor attached to the participant during the simulated critical care patient scenario. The Form titled Data Collection (Appendix 4) was used to record these data.

Heart rate

The participant was connected via electrocardiogram cables to the Criticare 8100 EP monitor in the simulation lab, and monitored and recorded during the entire session. Heart rate was operationally defined as the number of QRS complexes per minute as counted by the monitor, displayed on the screen, and recorded on the monitor paper. Heart rate was recorded every five minutes, concurrently with other physiological measures, and monitored continuously during the session.

Blood pressure

Blood pressure measurement during the sessions was obtained and recorded every five minutes, concurrently with other physiological measures, by the non-invasive blood pressure function of the Criticare 8100 EP monitor via the blood pressure cuff attached to the monitor and positioned on the participant's non-dominant upper arm. Blood pressure was operationally defined as the systolic and diastolic pressures measured by the monitor. The technique of this monitor is automatic oscillometric upon inflation. Cuff size was determined per American Heart Association guidelines which indicate that the cuff should have a bladder length that is 80% and a width that is at least 40% of arm circumference (a length-to-width ratio of 2:1) (American Heart Association, 2006b).

Respiratory rate

Respiratory rate was operationally defined as breaths per minute as measured continuously by impedance from the Criticare 8100 EP monitor via the ECG leads and cables, displayed on the screen, and recorded on the monitor paper. Respiratory rate was recorded at a frequency of every five minutes, concurrently with other physiological measures, and monitored continuously during the session.

Oxygen saturation

Oxygen saturation was operationally defined as the percent of hemoglobin that is saturated by oxygen as measured by the Criticare 8100 EP monitor pulse oximeter. A MultiSite ™ forehead probe pulse oximeter sensor attached to the Criticare 8100 EP monitor was worn by the participants continuously during the session. This provided continuous monitoring and left the participants' hands free. Oxygen saturation was recorded every five minutes of the session, concurrently with other physiological measures, and monitored continuously.

Cognitive Performance Variables

Cognitive performance was operationally defined as the Critical Care Score, Critical Care Percent Score, Critical Care Error and Omission Score and Critical Care Reaction Times during the simulated critical care patient scenario, and performance on the ANAM4 neurocognitive test battery (Center for the Study of Human Operator Performance, 2006).

Critical Care Score

A standardized checklist including all the required actions for the ventricular fibrillation ACLS Mega Code scenario was developed from the instructor materials published by the American Heart Association (American Heart Association, 2006a)(Appendix 5). The participants were scored on his/her performance based on a raw score. The checklist included each patient assessment, clinical examination, medication, or other action listed in order as recommended by the ACLS guidelines (American Heart Association, 2006a). A dichotomous scoring scale with 0 for incorrect or not done, and 1 for done correctly, was used for each item (Wayne et al., 2005). The Critical Care Score was defined as the number of correct actions on the scenario checklist, and was calculated by the researcher, an ACLS instructor with 17 years experience. The minimum score was 0 and the maximum score was 24.

Critical Care Score Percent

The Critical Care Score was converted to a percent.

Critical Care Reaction Times

The scenario began with a brief clinical history based on ACLS materials. The participant was instructed to direct and perform patient care tasks. The participant was recorded as they performed care during scenario and the recording was later reviewed and analyzed by the researcher. Physiological indices thresholds, consisting of observable changes in the simulated patient's condition, such as an oxygen saturation of 90%, a heart rhythm of ventricular fibrillation, a systolic blood pressure drop of 20 mm Hg or to 90 mm Hg, a respiratory rate below 10 breaths per minute, that required intervention by the participant were generated by the simulator and appeared on the simulated patient monitor. The time it took in minutes and seconds from the start of the scenario for the participant to be observed initiating the appropriate action was measured from the video recording using a stopwatch.

Critical Care Error and Omission Score

Critical Care Errors and Omissions were operationally defined as a deviation from the standard conduct as well as an omission of actions relating to standard operating instructions per ACLS guidelines (American Heart Association, 2006a). In order to measure the number of errors and omissions, the checklist of appropriate ACLS interventions was compared to the video recorded performance and errors and omissions were identified and given a score of 1 each, and added for a total score.

Neurocognitive test: The ANAM4

For comparison of cognitive performance as measured during the simulated patient care scenario and as measured in many other performance studies, selected tests from the ANAM4 were administered during the two sessions. The ANAM4, a standard neurocognitive performance test used in many performance studies, contains a library of tests of higher cognitive function (Center for the Study of Human Operator Performance, 2006). The PC-based software features the capability of customized test configurations, menu-driven software, repeated-measures, variable levels of difficulty, and automated scoring and reporting. The ANAM was developed by military researchers, and has been shown to detect cognitive changes in conditions relevant to military operational medicine, such as altitude and fatigue (Lowe et al., 2007).

The six ANAM4 tests selected for administration to the participants in this study were the Simple Reaction Time, 2-Choice Reaction Time, Code Substitution (Learning), Code Substitution (Delayed Memory), Mathematical Processing, and Logical Relations.

Simple reaction time was measured by presenting a series of symbols on the display. The user responded as quickly as possible to the display. Two-Choice reaction time was measured by having the user select a button based on the choice on the screen. Code Substitution (Learning) assessed visual search, sustained attention, and working memory by asking the user to compare a displayed digit-symbol pair with a set of defined digit-symbol pairs (the key). The user pressed designated buttons to indicate whether the pair in question represented a correct or incorrect mapping. In the Delayed Memory test, the comparison stimuli were again presented without the key. Basic computational skills, concentration, and working memory were tested during the Mathematical Processing test. Logical Relations assessed abstract reasoning and verbal syntax ability by asking the user to evaluate the truth of a statement.

Design

The design for this research study was a repeated measures 2 x 2 x 4 factorial experimental design, in which the first factor was a grouping variable and the second and third factors were repeated measures. In this study two of the stressors of flight were simulated, altitude-induced hypoxia, and military aircraft noise. Randomized block assignment resulted in a total of four equal groups of 15 subjects. Half of the subjects were exposed to military aircraft cabin noise conditions, and the other half were not exposed to noise. All participants were exposed to both the high and normal altitude conditions. Within the noise condition groups, subjects were randomly assigned and counterbalanced to the order of the altitude condition; the 8,000 feet/altitude-induced hypoxia condition followed by ground level, or ground level followed by the 8,000 feet/altitude-induced hypoxia condition. During each altitude condition, the physiological variables were measured at four time points. The design is depicted in Figure 5.

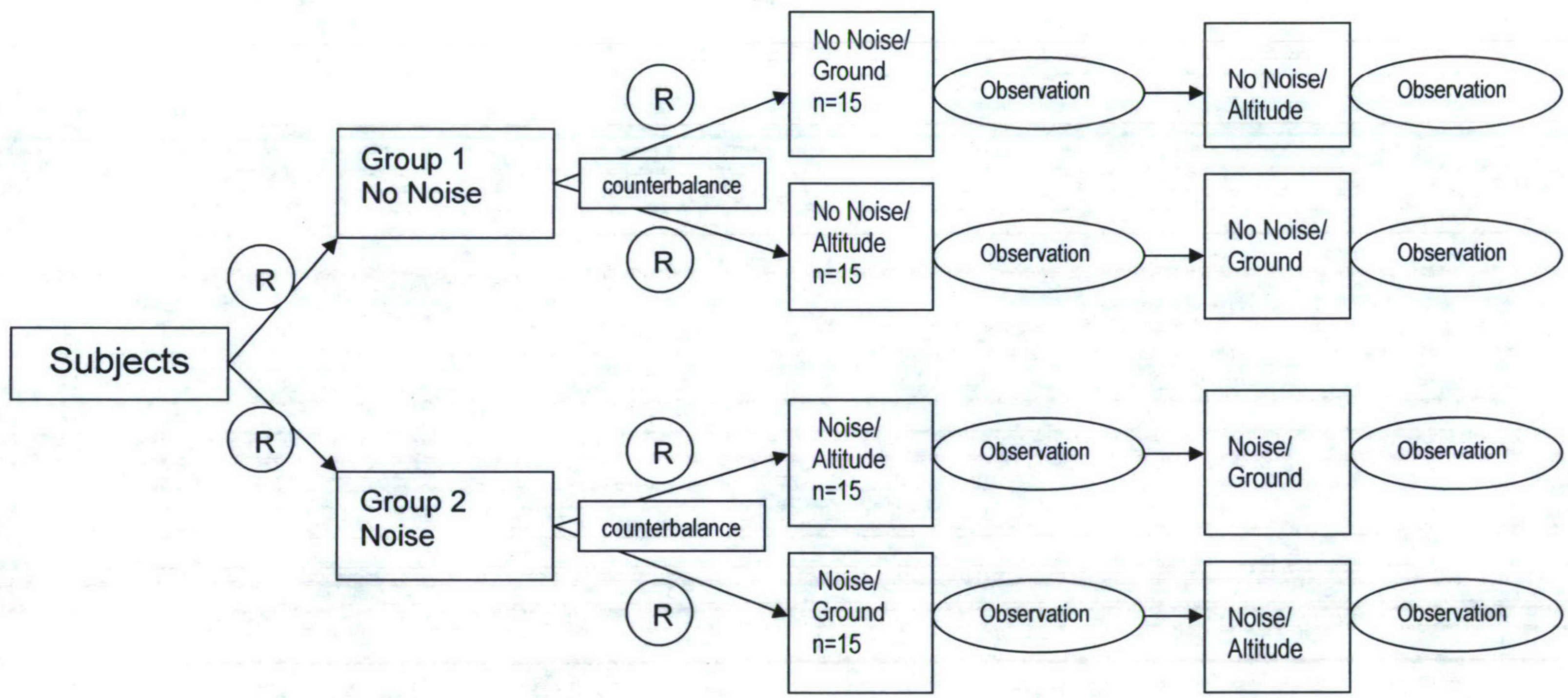

Figure 5. Study Design

Experimental Conditions

Noise

Military aircraft noise was simulated with a wave file from the Battlefield Acoustics Branch of the Air Force Research Laboratory, and regulated using a sound level meter. Ear protection in the form of earplugs was provided.

The noise condition was 30 minutes in duration during the acclimation period prior to the scenarios, and 30 minutes during each of two simulated patient care and cognitive testing sessions. During the testing sessions, a sound level meter (Extech Digital Sound Level Meter 407750, Extech Instruments Corporation, Waltham, MA) positioned at the waist of the simulated patient and the output from the Crown amplifier was adjusted to 86dB(A). The sound level was recorded at the start of each session.

Altitude

Each participant participated in both the high altitude and normal altitude conditions. The order was randomly assigned within the strata of the aircraft noise groups. The participants experienced a simulated cabin altitude of 8,000 feet, the altitude where a CCATT member is expected to care for critically ill patients. A cabin altitude of 8,000 feet creates an environment equivalent to breathing in 15% oxygen versus the usual 21% (Darwish, 2003; Samuels, 2004). To simulate cabin altitude of 8,000 feet, the participant wore a mask and air and oxygen were closely regulated and controlled to deliver 15% oxygen. For the ground altitude condition, the participant wore a mask and air and oxygen were closely regulated and controlled to deliver 21%. The altitude intervention components were single-blinded; the volunteer wore the mask in both conditions and did not know which air mixture he/she was breathing.

One strength of this design was that the within- and between subject differences were tested, and interactions between the two factors were examined. Other strengths were the random assignment to between subjects groups and differences in post-treatment measures could not be attributed to individual characteristics, such as motivation or intelligence. Equivalency before treatment was controlled by each subject serving as his or her own control (Girden, 1992). Another positive feature was the use of counterbalancing. Counterbalancing is a way of presenting the different levels of treatment, such that each one occurs equally and in all possible sequences. Counterbalancing served to counteract fatigue, practice, and carry-over effects (Girden, 1992).

Sample

The participants were a convenience sample of registered nurses in the Air Force, Army, or Navy; Active Duty, National Guard, or Reserves; they were recruited from military and civilian organizations in the Baltimore/Washington, D.C. area. These included The Malcolm Grow USAF Medical Center at Andrews Air Force Base, Walter Reed Army Medical Center, The White House Medical Unit, the University of Maryland School of Nursing, and the U.S.A.F. Center for Sustainment of Trauma and Readiness Skills at the University of Maryland Medical System Shock Trauma Center. The participants were required to have experience in a critical care or emergency setting, and have completed ACLS training. The registered nurses could have any educational preparation. Physicians were recruited but none volunteered to participate. With Commander and/or Institutional Review Board (IRB) approval, and University of Maryland IRB approval, the researcher recruited participants via brochures (Appendix 6) and informational sessions. The researcher also visited the military facilities in the national capital area to recruit participants, and encouraged referrals. The military critical care and emergency clinicians stationed in the national capital region were estimated to number in excess of 750 officers. This study included 60 members of the armed services 49 years old or younger, assigned to duty in the national capital area. Each participant was informed that the entire study would take approximately 3.5 hours to complete.

Inclusion Criteria

1. Registered nurses and physicians
2. The registered nurses could have any educational preparation
3. Members of the Air Force, Army, or Navy; Active Duty, National Guard, or Reserves
4. Experience in a critical care or emergency setting
5. Completion of ACLS training
6. The participants met the physical requirements of Air Force Physiological Training and Physiological Training Personnel/ Operational Support Flying Duty (Aviation Service Code 9C), as outlined in Air Force Instruction 48-123, Attachment 8 (2001). Criteria included a physical exam free of heart or respiratory disease, abdominal mass or hernia, neurological abnormalities or migraines, blood hematocrit above 36% for a female, or above 38% for a male, weight within military standards for height, blood pressure below 150 mm Hg systolic and 95 mm Hg diastolic, and resting pulse below 100 beats per minute.
7. Participants were 49 years old or younger, as the risk of cardiac events increases significantly above this age, and the average age range for support personnel such as

physicians and nurses likely to deploy is from 24.6 to 48.5 years (Air Force Personnel Center, 2006; Elwood, Morgan, Brown, & Pickering, 2005).

8. Participants were able to read and speak English.

9. Participants were able to tolerate wearing a mask and were not claustrophobic while wearing a mask.

Exclusion Criteria

1. Any participants with a positive pregnancy test would have been excluded and advised to contact their health care provider for further guidance. The pregnancy test was done using a commercially available pregnancy test strip (Calhoun Industries, Inc). Results were documented on the Health Status/Inclusion and Exclusion Form (Appendix 3) developed for the study. None of the participants had a positive pregnancy test.

2. Participants who had donated blood in the last 72 hours would have been excluded, as this also excludes military personnel from flying duty. None of the participants had donated.

Determination of Sample Size/Power Analysis

For the within-subjects comparison between ground level and altitude of 8,000 feet, inclusion of 32 participants was expected to have 80 percent power to detect an effect size of 0.5 standard deviations based on a five percent 2-sided significance level. This sample size should have been adequate because in previous studies on ACLS testing (Wayne et al., 2005) and cognitive task error rates with hypoxia (Bartholomew et al., 1999), the observed effect size was similar. To detect between-subjects differences in the noise-no noise comparisons across groups, with an effect size of .75 standard deviations, 30 participants per group, or a total of 60 participants was estimated to be required, as determined by using the nQuery Advisor version 4.0 power analysis software, developed by Elashoff. With an attrition rate estimated at 10%, the total sample size required for this study was 66 participants. None of the participants were excluded, so a total of 60 participants were enrolled.

Human Subjects Protections

The researcher obtained informed consent from each participant prior to the beginning of the study. During the consent procedures, participants were informed that they could withdraw from participating in the study at any time, and that they could refuse to answer any questions. Written informed consent forms with verbal explanations and opportunity for questions were provided for each participant. All participants were treated in compliance with Air Force Instruction FI 40-402, and applicable Food and Drug Administration, Health and Human Services and Health Insurance Portability and Accountability Act (HIPAA) guidelines.

Care was taken not to exert undue influence or pressure to participate on other military members of junior rank or students. Recruitment by the researcher was accomplished in civilian clothes, and rank was not used in any communication or solicitation. Information from the study was not reported to the individual participant's unit or commander. Students recruited were not students of the researcher. No information about participants was provided to any faculty member or placed in any student's record. Recruitment in an academic setting occurred with the instructors outside the room.

To protect participants' privacy, names were not attached to test results. The results were only identifiable by a unique code that allows statistical analysis and data matching. Documents, videotapes and computer files were kept in a locked file cabinet in the researcher's home office. Videotapes have only been viewed by the investigator and do not have the participants name on them. Access to the computer data was fingerprint and password protected. The computer was not network connected. All participants' research records have and will be kept confidential. Participants will not be identifiable in any publications or reports on the study or data.

The research protocol was reviewed and approved by the University of Maryland IRB, the 89^{th} Medical Wing IRB, National Naval Medical Center IRB, and the Uniformed Services University IRB, and recruiting at Walter Reed Army Medical Center and the Center for Sustainment of Trauma and Readiness Skills was approved by the Commanders. All racial, ethnic, and gender groups were recruited for this study.

Potential Risks

Before inclusion in the study, volunteers were informed of the potential risks associated with this study. As part of this study, volunteers were asked to:

1. Provide a drop of blood from a fingerstick for determining their hematocrit
2. Females to provide a urine sample for pregnancy testing
3. Wear a face mask to breathe the gas mixture of air at cabin altitude of 8,000 feet (15%) and ground level (21%)
4. Use the standard earplugs (Aearo EAR brand) that are issued for CCATT patient movement to protect hearing during simulation of the noise levels in cabin of fixed wing military aircraft. The time of exposure was approximately 120 minutes, and measured noise was 86dB.

5. Wear a heart rate monitor
6. Have blood pressure measurements checked periodically throughout the experiment
7. Wear an oxygen saturation monitor
8. Perform simulated critical care tasks at ground level and altitude of 8,000 feet, with either ambient noise or simulated military aircraft cabin noise
9. Complete questionnaires on demographic information, health information, and fatigue
10. Complete a computerized neurocognitive assessment tool

Emergency equipment and phone numbers were immediately available. This included oxygen, a mask for delivery, and an Automated External Defibrillator. The University of Maryland Medical Center Emergency Department is immediately across the street from the School of Nursing in the event of an emergency, but no adverse events occurred. One Advanced Cardiac Life Support provider was present during all testing. Participants were continuously monitored during the study for heart rate, blood pressure, respiratory rate, and pulse oximetry. Potential risks as identified prior the study are outlined in Appendix 7.

Confidentiality

To protect participants' privacy, names were not attached to test results. The results are only identifiable by a unique code that allows statistical analysis and data matching. Documents, videotapes and computer files were in a locked file cabinet in the researcher's home office. Videotapes have only been viewed by the investigator and do not have the participants name on them. Computer data were fingerprint and password protected. All participants' research records were kept confidential. Participants will not be identifiable in any publications or reports on the study or data.

Possible benefits

This study was designed for research purposes only and did not have a direct beneficial effect on the participants. Results may impact care and performance of critical care personnel on AE missions in the future.

Compensation

Eligible participants were paid $50 compensation for the blood draw. A few participants refused compensation.

Data Safety Monitoring Plan

IRB approval was obtained before the study commenced. Files from the IRB were maintained by the investigator. Safety Emergency equipment and phone numbers were immediately available in the laboratory used for the research protocol. Participants were continuously monitored during the study for heart rate, blood pressure, respiratory rate, and pulse oximetry. Testing would have been stopped if a participant displayed a pulse oximeter reading below 85% or a heart rate above 130 beats per minute. Oxygen would have been delivered to the participant via mask until pulse oximetry was above 95% and heart rate was below 100 beats per minute. No adverse events occurred.

Participants were given 24-hour access to the cell phone of the investigator to report any adverse events after the conclusion of the study.

Setting

The study took place in the Simulated Patient Laboratory at the University of Maryland School of Nursing. Participants performed skills relating to management of a simulated critical care patient. The high fidelity simulator (SimMan, Laerdal, N.Y.) in the laboratory is used to teach and evaluate anesthesia, critical care, emergency, and peri-operative skills, and can be programmed to physiologically respond to a variety of realistic scenarios. This state-of-the-art laboratory has a simulation manikin, computer interface with the manikin to allow programming of scenarios, and monitors to display the patient's vital signs/physiological parameters, and medical equipment needed to treat and maintain a critically ill patient. The equipment available was the same or similar to equipment that is used on a CCATT mission, and by all the military medical services to care for patients in a deployment or in the AE system. The laboratory also has video and audio equipment that allowed recording of participant performance during the experiment for later analysis and review. Photographs of the interior of a C-17 military cargo aircraft were enlarged and hung around the patient care area to enhance realism of the setting.

Instrumentation, Reliability, and Validity

Equipment

Altitude of 8,000 feet

The HYP123 Hypoxic Generator (Hypoxico, Inc. New York) was used to deliver the air and an oxygen monitor (Hypoxico, Inc New York) continuously measured the oxygen percentage of the hypoxic air to ensure the appropriate gas mixture. Calibration to room air was completed prior to each session, and to 100% oxygen once a week during the study.

Noise of Aircraft Cabin

Sound aboard a C-17 military aircraft was simulated with an 80 minute wave file equivalent to the sound aboard a C-17 flight during cruising altitude that is played at an

A-weighted sound level of 86dB. The average sound level in the cabin during C-17 flight is 86 dB as measured by the Air Force Research Laboratory Battlefield Acoustics Branch (F. Mobley, personal communication, March 20, 2007). An Extech (Extech Instruments Corporation, Waltham, MA) sound level meter (Model 407750, accurate to ± 1.5 dB, with a range of 30 to 130 dB) was placed at the waist of the simulated patient and the sound output from the Bose sound system was adjusted to 86dB for the duration of the session.

Earplugs

The earplugs provide a noise reduction rating of 29 decibels (Aearo Company, 2007). If an environmental noise level measured at the ear is 86 dB(A), then the level of noise entering the ear of someone using these earplugs is approximately 57 dB(A) (Aearo Company, 2007).

Heart rate

The accuracy of the heart rate as measured by the Criticare 8100 EP monitor is ± 1 BPM or ± 1% (ECG), whichever is greater (Criticare 8100 EP Monitor, 2007). The radial, pulse oximeter, and ECG heart rates were compared to ensure accuracy. Steps to minimize artifact were perfected during a pilot session prior to start of the study.

Blood pressure

Criticare 8100 EP monitor non-invasive blood pressure (NIBP) was compared to an auscultated blood pressure to verify accuracy prior to each session. Blood pressure cuff size was determined per American Heart Association guidelines which indicate that the cuff should have a bladder length that is 80% and a width that is at least 40% of arm circumference (a length-to-width ratio of 2:1) (American Heart Association, 2006b). The accuracy of the NIBP transducer is ± 2 bpm or ± 2%, whichever is greater (Criticare 8100 EP Monitor, 2007).

Respiratory rate

Accuracy of respiratory rate as measured by the Criticare 8100 EP monitor is ± 1% or ± 1 breath/minute, whichever is greater (Criticare 8100 EP Monitor, 2007) Steps to minimize artifact were perfected during a pilot session prior to start of the study.

Oxygen saturation (SpO_2)

Accuracy of pulse oximetry measured with a Criticare 8100 EP monitor and a MultiSite ™ forehead pulse oximeter sensor is ± 2% at ranges of 70-99%; ± 3% at ranges 50-70% (Criticare 8100 EP Monitor, 2007).

i-STAT hematocrit

The i-STAT whole blood analyzer is a hand-held device that tests blood results drawn via a fingerstick and introduced into a cartridge specific for each test or a series of tests. The device is approved for use in patient care, and is the main blood analyzer used by Air Force personnel in the field. In the cartridge, the solid-state chips contain biosensors configured to perform specific tests with chemically sensitive membranes and films containing reagent chemicals. Sensors perform other functions such as monitoring the quality of the sample being tested. Silicon-type microfabrication utilizing high quality materials that exhibit exceptional stability allows consistent reproducibility in a high-volume manufacturing environment. This well accepted technology ensures that each cartridge offers a high level of accuracy and reliability (i-STAT, 2006). A study comparing prehospital with emergency department laboratory values showed a high correlation (r=0.95) in hematocrit tests (Tortella, Lavery, Doran, & Seigel, 1996).

Quality Control testing with the electronic external simulator was completed on the iSTAT machine each day of use during the study.

Self-report Measures

Fatigue

The 10-item FAS was developed in the Netherlands. A 5-point Likert frequency rating scale accompanies the items. Reliability (Cronbach's alpha = 0.87) and content validity were supported in an initial study (Michielsen, De Vries, Van Heck, Van de Vijver, & Sijtsma, 2004). In order to further test the psychometrics, as part of a longitudinal study, workers with at least 20 working hours per week completed the FAS (Michielsen, De Vries, & Van Heck, 2003). They also completed four related fatigue measures, a depression questionnaire and an emotional stability scale.

The authors analyzed internal consistency with Cronbach's alpha with a result of 0.90. Exploratory factor analysis supported one construct with loadings of 0.55 to 0.82, and the single factor explained 53% of the variance. Correlations between the FAS and other measures of fatigue were high, supporting convergent validity. Evidence of divergent validity was demonstrated with principle component analyses of the FAS and depression items, as well as the FAS and emotional stability items. The FAS items and depression items were shown to be correlated to separate factors on the analysis, with some cross-loadings. The separate correlations were expected as depression may be associated with fatigue. The factor analysis of the emotional stability items and the FAS items showed two distinct factors.

The developers of the FAS have tested its psychometrics in another study of Dutch sarcoidosis patients, as well as a sample of Croatian sarcoidosis patients (De Vries, Michielsen, Van Heck, & Drent, 2004; Michielsen, De Vries, Drent, & Peros-Golubicic, 2005). Test-retest reliability in the Dutch patients was high, at 0.89. Content validity, construct validity, and internal consistency were supported in both studies.

Cognitive Measures

Critical Care Score and Critical Care Score Percent

A standardized checklist for all the required actions for the ventricular fibrillation ACLS Mega Code scenario was developed from the instructor materials published by the American Heart Association (Appendix 5). Content validity was evaluated by two ACLS instructors. The checklist was evaluated during the pilot sessions. Interrater reliability of the final scoring checklist with four ACLS instructors was established during the study and found to have a Chronbach's alpha of 0.981.The Critical Care Score and Critical Care Score Percent were determined.

The simulation protocols were developed based on critical care ACLS certification skill requirements, and the same assessments and actions were required for the scenarios used for each environment. Using computer software, the simulator displayed multiple physiologic and pharmacologic responses. Simulator assessment has been demonstrated to have good internal consistency (alpha = 0.71-0.76) and excellent interrater reliability (correlation = 0.94-0.96; $P < 0.01$; kappa = 0.81-0.90) (Schwid et al., 2005).

Critical Care Reaction Times

The time it takes in minutes and seconds for the participant to do the appropriate action was measured from the video recording using a Traceable® 60-Memory Stopwatch. Accuracy is to 0.001%. To assure accuracy an individually serial-numbered

Traceable® Certificate is provided from a ISO 17025 calibration laboratory accredited by A2LA. The device indicates traceability to standards provided by NIST (National Institute of Standards and Technology).

Critical Care Error and Omission Score

Error rate was operationalized as the number of errors during the simulated scenario sessions. To measure the number of errors, the checklist of appropriate ACLS interventions was compared to the video recorded performance and errors were identified by the researcher. Interrater reliability of the final scoring checklist with four ACLS instructors was established during the study and found to have a Chronbach's alpha of 0.981.

Standard cognitive test: The ANAM4

The ANAM4 has been used in studies on environmental stressors, neurological conditions, and drug affects in military and civilian populations and has demonstrated validity and reliability (Levinson, Reeves, Watson, & Harrison, 2005; Lowe et al., 2007). Test-retest reliability ranged from 0.85 to 0.66 on the tests. Validity was 0.51 and 0.66 (both Ps <.001) as measured by correlational analyses with performance on other cognitive tests (Blieberg, Kane, Reeves, Garmoe, & Halpern, 2000). The primary dependent measure for the six ANAM tests was throughput (TP) score (number of correct responses per minute). The TP score is considered a measure of cognitive efficiency by measuring the trade-off between speed and accuracy.

Data collection procedures

1. Recruitment

The participants were a convenience sample of registered nurses in the Air Force, Army, or Navy; Active Duty, National Guard, or Reserves; they were recruited from organizations in the Baltimore/Washington, D.C. area. The researcher recruited participants from military and civilian facilities via flyers, brochures and informational sessions. The researcher also visited organizations to recruit participants, and encouraged referrals.

2. Informed Consent

The purpose and details of the study were discussed with the registered nurses who volunteer to participate. Written informed consent was obtained.

3. Screening

a) The participants were questioned about their health history and Operational Support Flying physical. If they stated they had a current flying physical, the exam was waived.

b) The participant had a physical completed and documented by the researcher, a registered nurse. The exam included observation, palpation and auscultation as applicable to assess head, neck, chest, abdomen, and extremities. Height and weight were obtained to determine if they were within Air Force physical standards. Vital signs were obtained. The participant answered questions about their health status, including health history, smoking habits, and caffeine ingestion.

c) Participants had a finger stick for determination of their blood hematocrit with an iSTAT blood analyzer.

d) If the hematocrit had been below 36% for females or 38% for males, the participant would have been given a letter advising them to see their health care provider for further guidance, and a hematocrit and iron information sheet. They would have then been excluded from the study. No participant had a low hematocrit.

e) Urine pregnancy testing of female participants was completed to rule out pregnancy.

f) A woman with a positive pregnancy test would have been given a letter advising her to see her health care provider for further guidance. She would have then been excluded from the study. No participant had a positive pregnancy test.

4. Each participant was randomized to military aircraft noise or ambient noise condition.

5. Each participant was randomized to 8,000 feet (15%) or ground altitude (21%) oxygen levels as first of two testing conditions. The altitude intervention components were single-blinded; the volunteer did not know which air mixture he/she was breathing

6. Preparatory Steps for Session One

a) The Fatigue Assessment Scale and the demographic questionnaire were completed by the participant

b) The participant was instructed on the ANAM4 and completed an introductory session, to allow practice and familiarization with the test.

c) Equipment to continuously monitor the heart rate, respiratory rate, oxygen saturation, and to measure blood pressure was applied to the participant. The blood pressure cuff was placed on the non-dominant arm. The appropriate cuff size was used per American Heart Association standards based on arm circumference (American Heart Association, 2006b). The pulse oximeter probe was placed on the forehead, and the three cardiac leads were attached to ECG monitoring electrodes placed on the right upper and left upper chest and left lower abdomen. Baseline data were collected with participants sitting and standing.

d) Another set of vital signs data were collected with participants standing at the head of simulator manikin.

e) The participants were introduced to the Simulator. This introductory session was conducted to ensure familiarization with the simulator, equipment, and supplies.

f) The mask with the appropriate mix of gases delivered was placed on the participant's face.

g) Each participant in the noise arm was given E-A-R classic (NSN 6515-00-137-6345, Aearo Company, Indianapolis) foam earplugs that are approved for use during AE missions for hearing protection. The researcher supervised insertion of earplugs per manufacturer directions that accompany the dispenser. If the sessions were to include noise, the recording was switched on and adjusted to 86dD. If this was a no noise participant, the ambient noise level was measured. The average ambient noise level was measured as 54dBA.

h) The participant remained at the first condition for 30 minutes prior to testing to allow for acclimation. Recreational reading material was provided.

i) Video recording equipment was activated to record the testing sessions

7. Testing Session One

a) The participant performed the first patient care scenario. This lasted 20 minutes.

b) Heart rate, respiratory rate, and oxygen saturation were monitored continuously and recorded every 5 minutes. Blood pressure was obtained and recorded every 5 minutes.

c) The ANAM4 was administered, which took about 10 minutes, and then the first session ended.

8. Between Testing Sessions

After the first session, the participant removed the mask and earplugs, had vital signs taken again, and then had a 15-minute break.

9. Preparatory Steps for Session Two

a) The participant resumed the study prior to the second condition with reapplication of the monitors and mask, and delivery of the appropriate mix of gases (those of the condition not tested in the first session).

b) Earplugs were inserted as indicated. If the session was to include noise, the recording was switched on and adjusted to 86dB. If this was no noise participant the ambient noise level was measured again.

c) The participant remained at the second condition for 30 minutes prior to testing. Recreational reading material was provided.

10. Testing Session Two

a) The participant performed the second patient care scenario. This lasted 20 minutes.

b) Heart rate, respiratory rate, and oxygen saturation were monitored continuously and recorded every 5 minutes. Blood pressure was obtained and recorded every 5 minutes.

c) The ANAM4 was administered again, which again took about 10 minutes, and then the second and final session concluded.

11. Conclusion

At the conclusion of the session the participant removed the mask and earplugs, and a final set of vital signs were collected. The participant was debriefed on the scenarios if desired. The measurement schedule can be found in Table 3.

Table 3

Measurement Table

Variable	**Instrument**	**Prior to Session 1**	**Session 1**	**Between Sessions**	**Session 2**	**Conclusion**
Participant Demographics	Self–report Questionnaire	X				
Fatigue	FAS Instrument	X				
Physiological Performance at Altitude: Heart Rate	Criticare 8100 EP monitor	Measured at baseline, sitting and standing	Continuously monitored, recorded every 5 minutes for a total of 4 measurements	X	Continuously monitored, recorded every 5 minutes for a total of 4 measurements	X
Physiological Performance at Altitude: Blood Pressure	Criticare 8100 EP III monitor	Measured at baseline, sitting and standing	Monitored and recorded every 5 minutes for a total of 4 measurements	X	Monitored and recorded every 5 minutes for a total of 4 measurements	X
Physiological Performance at Altitude: Respiratory Rate	Criticare 8100 EP monitor	Measured at baseline, sitting and standing	Continuously monitored, recorded every 5 minutes for a total of 4 measurements	X	Continuously monitored, recorded every 5 minutes for a total of 4 measurements	X
Physiological Performance at Altitude:	Criticare 8100 EP monitor	Measured baseline, sitting	Continuously monitored, recorded every	X	Continuously monitored, recorded every	X

Variable	Instrument	Prior to Session 1	Session 1	Between Sessions	Session 2	Conclusion
Oxygen Saturation		and standing	5 minutes for a total of 4 measurements		5 minutes for a total of 4 measurements	
Cognitive Performance at Altitude: Critical Care Score and Percent	Videotaped Critical Care Scenario: Critical Care Score Sheet		Scenario recorded, score determined after review		Scenario recorded, score determined after review	
Cognitive Performance at Altitude: Critical Care Reaction time	Videotaped Critical Care Scenario: Critical Care Reaction Time		Scenario recorded, times determined after review		Scenario recorded, times determined after review	
Cognitive Performance at Altitude: Critical Care Error and Omission Score	Videotaped Critical Care Scenario: Critical Care Error and Omission Score		Scenario recorded, score determined after review		Scenario recorded, score determined after review	
Cognitive Performance at Altitude: ANAM Throughputs	ANAM4 Cognitive Performance Tests		Measured after scenario		Measured after scenario	

X = Measured once

Data Collection Forms

The forms used to collect data were the Fatigue Assessment Form (Appendix 1), the Demographic Questionnaire (Appendix 2), the Health Status/Inclusion and Exclusion Form (Appendix 3), the Data Collection Form (Appendix 4), which was used to record data during the testing sessions and record the assignment to conditions, and the ACLS Checklist Form (Appendix 5).

Data Analysis

Data Management

Data storage and management was conducted on a laptop computer. This computer is fingerprint and password protected and the data were backed up daily by the researcher, who was the only individual with access to the storage drives. One copy of the files was maintained in a locked desk off-site. The statistical package used for data analysis was SPSS 15.0. Data were entered into SPSS 15.0 by the researcher, and was double-checked for accuracy manually and statistically. Files from the ANAM4 were directly loaded into SPSS.

Statistical Analysis: Descriptive statistics

Means and standard deviations were calculated for all continuous variables. Descriptive statistics were used to describe the sample, as collected on the demographic questionnaire included age, gender, race and ethnicity, education level, profession, years experience, years critical care and/or emergency experience, and deployment experience (role, times, length, type of unit type code/position, number of patients transported) (Appendix 2).

Statistical Assumptions

Descriptive analysis of all the outcome variables was completed to examine the data for outliers and missing data. Assumptions for RM ANOVA and multiple regression were tested, which include sphericity, normality, and homogeneity of variance (Girden, 1992). Missing data were handled with mean substitution.

Research Questions, Hypotheses, and Statistical Testing

Analysis Plan

Research Question 1. What are the effects of military aircraft noise and altitude-induced hypoxia on cognitive and physiological performance of CCATT personnel during a simulated critical care patient scenario?

Hypothesis 1A: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise.

Hypothesis 1B: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise.

Hypothesis 1C: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with altitude-induced hypoxia.

Hypothesis 1D: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with altitude-induced hypoxia.

Hypothesis 1E: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise and altitude-induced hypoxia.

Hypothesis 1F: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise and altitude-induced hypoxia.

Differences in cognitive performance and physiological performance were analyzed using a repeated measures analysis of variance (RM ANOVA) with altitude and time as within-subjects factors, and military aircraft noise as a between-subjects factor.

Research Question 2. What are the effects of fatigue and clinical experience on cognitive and physiological performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia?

Hypothesis 2A: Fatigue and clinical experience predict cognitive performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia.

Hypothesis 2B: Fatigue and clinical experience predict physiological performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia.

A multiple regression model was developed to determine the independent contribution of fatigue and clinical experience to cognitive and physiological performance with military aircraft noise and altitude-induced hypoxia.

SUMMARY

This chapter included the operational definitions of the variables of interest in this study. Additionally, the experimental conditions were described. The research design and procedures were outlined, and finally the statistical analysis was described. Chapter Four includes the analytical results.

CHAPTER IV: RESULTS

The statistical results of the data analysis are provided in three sections in this chapter. The characteristics of the participants in the study are described in the first section. The second section provides the descriptive statistics for the variables of interest. The third section contains the results of the research questions organized by hypotheses.

THE PARTICIPANTS

A total of 60 military registered nurses from, or on temporary duty in, the Baltimore-Washington area were included in the study. Physicians were recruited but did not volunteer to participate. There were no dropouts and none of the participants were excluded after consent. Participants had experience in Advanced Cardiac Life Support skills.

Demographic Characteristics of the Participants

The following demographic characteristics are statistically described: age, gender, race, height, weight, smoking history, education, healthcare specialty, time in specialty, deployment and patient transport experience, years in the military, branch of service, and rank. See Table 4 for the demographic characteristics of the participants. The ages ranged from 22-49 years (M = 39.23, SD = 7.25). Twenty-five (41.7%) of the participants were male. Forty-three (71.7%) of the participants were white, 13 (21.7%) were black, 1 was American Indian (1.7%), and 3 (5.0%) were multi-racial. Height ranged from 61 to 73 inches (M = 67.27, SD = 3.41). Weight ranged from 105 to 245 pounds (M = 166.40, SD = 32.41). The majority of the participants had never smoked (78.3%), and only three currently smoke (5.0%). Forty-one (68.4%) participants gave critical care nursing as their current primary specialty. Months of experience ranged from 3 to 255 (M = 93.15, SD = 67.47). Thirty-two of the participants had been deployed (53.3%), and during deployment, 18 (30.0%) transported patients. Time in military service ranged from 3 months to 30 years (M = 14.05, SD = 7.42). Forty participants were in the Air Force (66.7%), 13 (21.7%) were in the Army, and 7 (11.7 %) were in the Navy. Thirty-two (53.3%) of the participants were company grade or junior officers (01-03), and 28 (46.7%) were field grade or senior officers (04-06).

Table 4

Demographic Characteristics of participants in the study sample

Characteristic	n (%)	Mean (SD)	Minimum	Maximum
Age		39.23 (7.25)	22	49
Gender				
Male	25 (41.7)			
Female	35 (58.3)			
Race				
White	43 (71.7)			
Black	13 (21.7)			
American Indian	1 (1.7)			
Multi-racial	3 (5.0)			
Height (inches)		67.27 (3.41)	61	73
Weight (pounds)		166.40 (32.41)	105	245
Smoking History				
Never Smoked	47 (78.3)			
Quit	10 (16.7)			
Currently Smoke	3 (5.0)			
Healthcare Specialty				
Critical Care		41 (68.4)		
Non-critical Care		19 (31.6)		
Time in Specialty (months)		93.15 (67.47)	3	255
Deployment Experience	32 (53.3)			
Patient Transport Experience	18 (30.0)			
Years in Military		14.05 (7.42)	.3	30
Branch of Service				
Air Force	40 (66.7)			
Army	13 (21.7)			
Navy	7 (11.7)			
Rank				
01	5 (8.3)			
02	4 (6.7)			
03	23 (38.3)			
04	19 (31.7)			
05	7 (11.7)			
06	2 (3.3)			

Group Comparison

Participants were randomly assigned to either the aircraft noise (n = 30) or the ambient noise (n = 30) noise group. The participants were compared based on the noise group to which they were randomized, aircraft cabin noise or ambient noise. Table 5 includes demographic information on the participants, data on experience, Fatigue Assessment Scores, and baseline physiological parameters according to noise exposure group. T-tests were used to compare continuous variables. There were no statistically significant differences found in age, height, weight, Fatigue Assessment Scale scores, Time in Specialty, Time in Military, Heart Rate, Systolic Blood Pressure, Diastolic Blood Pressure, Respiratory Rate, or Oxygen Saturation between those assigned to the noise and no noise groups. Chi-square was used to analyze differences in the categorical variables. The categories were combined to conduct the analysis when it was necessary to meet the assumption of 5 or more scores per cell. There were no statistically significant differences in the categorical variables between the two groups.

Table 5

Comparison of Demographic, Questionnaire, and Baseline Physiologic Data for Participants Randomly Assigned to the Aircraft Noise (Noise) and Ambient (No Noise) Groups

	No Noise (N=30)	Noise (N=30)	t (df = 58)	Chi-square (df =1)	Level of Significance
Age (yrs)	38.9 ± 8.64	39.57 ± 5.66	-0.353		0.725
Height (inches)	66.87 ± 3.36	67.67 ± 3.45	-0.908		0.367
Weights (lbs)	164.2 ± 33	168.60 ± 31.94	-0.523		0.603
Education [a]				0.0	1.0
Bachelors (%)	10 (33.3)	8 (26.7)			
Some Graduate School (%)	6 (20.0)	7 (23.3)			
Advanced Degree (%)	14 (46.7)	15 (50.0)			
Gender (% male)	9 (30.0)	16 (53.3)		2.47	0.116
Race [b]				0.0	1.0
White (%)	21 (70.0)	22 (73.3)			
Black (%)	7 (23.3)	6 (20.0)			
American Indian/ Alaskan Native (%)		1 (3.3)			
Multi-racial(%)	2 (6.7)	1 (3.3)			
Smoking History [c]				0.126	0.722
Never Smoked (%)	22 (73.3)	25 (83.3)			
Quit more than 6 months ago (%)	5 (16.7)	2 (6.7)			
Quit less than 6 months ago (%)	2 (6.7)	1 (3.3)			
Currently Smoke (%)	1 (3.3)	2 (6.7)			
Fatigue Assessment Scale (FAS)	17.33 ± 3.55	16.50 ± 4.16	0.835		0.407
FAS Transformed	4.14 ± .421	4.03 ± .50	0.921		0.361
Healthcare Specialty				2.773	0.096
Critical Care (%)	17 (56.7)	24 (79.9)			
Other (%)	13 (43.3)	6 (21.1)			
Time in specialty (months)	88.70 ± 73.93	97.60 ± 62.47	-0.508		0.614

	No Noise (N=30)	Noise (N=30)	t (df = 58)	Chi-square (df =1)	Level of Significance
Deployment Experience (%)	13 (43.3)	19 (63.3)		1.67	0.196
Patient transport experience (%)	6 (20.0)	12 (40.0)		1.98	0.159
Time in military (yrs)	13.02 $\pm$ 8.71	15.07 $\pm$ 5.82	-1.071		0.289
Branch of Service [d]				0.0	1.0
Air Force (%)	20 (66.7)	20 (66.7)			
Army (%)	6 (20.0)	7 (23.3)			
Navy (%)	4 (13.3)	3 (10.0)			
Rank [e]				0.067	0.796
01 (%)	3 (10.0)	2 (6.7)			
02 (%)	3 (10.0)	1 (3.3)			
03 (%)	9 (30.0)	14 (46.7)			
04 (%)	10 (33.3)	9 (30.0)			
05 (%)	3 (10.0)	4 (13.3)			
06 (%)	2 (6.7)				
Heart Rate	67.13 $\pm$ 10.30	68.93 $\pm$ 11.06	-0.652		0.517
Systolic Blood Pressure	112.40 $\pm$ 12.53	117.57 $\pm$ 13.48	-1.538		0.130
Diastolic Blood Pressure	76.53 $\pm$ 8.30	77.73 $\pm$ 9.2	-0.088		0.930
Respiratory Rate	14.27 $\pm$ 1.55	14.47 $\pm$ 1.94	0.441		0.661
Oxygen Saturation	98.83 $\pm$ .379	98.83 $\pm$ .461	0		1.0

a χ^2 Comparison of Bachelors and Some Graduate Education vs. Advanced Degree
b χ^2 Comparison White vs. Non-white
c χ^2 Comparison of Never Smoked vs. Current or Past Smoking
d χ^2 Comparison of Air Force vs. Non-Air Force
e χ^2 Comparison Company Grade rank (01-03) vs. Field Grade rank (04-06)

DESCRIPTIVE STATISTICS

Descriptive statistics were evaluated for each variable. The dependent variables (Critical Care Score, Critical Care Score Percent, Critical Care Errors and Omissions Score, Critical Care Reaction Times, ANAM Throughput Scores, Heart Rate, Systolic Blood Pressure, Diastolic Blood Pressure, Respiratory Rate, and Oxygen Saturation) are all continuous variables at the interval/ratio level of measurement. All variables were closely examined for missing data, outliers and normality.

Cognitive Data

Critical Care Score, Critical Care Score Percent, and Critical Care Errors and Omissions Score were found to have normal distributions (see Table 6). Of the 24 Critical Care Reaction Times observed, Reaction Times 4, 5, 6, 7, 14, 15, and 16 were considered for analysis because less than 5% of the totals of these times were missing. The reaction times are the time from the beginning of the scenario until the participant completed the following tasks from the ACLS Checklist Form (Appendix 5):

CCRT4: Puts on oxygen

CCRT5: Hangs IV fluids

CCRT6: Starts BVM (bag-valve-mask) breathing

CCRT7: Intubates/Advanced Airway

CCRT14: Defibrillates 1st time

CCRT15: Gives epinephrine 1 mg or Vasopressin 40 U IV

CCRT16: Gives Amiodarone 300 mg IV or Lidocaine, 1.5 mg/kg IV

Several participants omitted other tasks on the ACLS checklist and therefore these times were not measurable. Mean substitution was used to handle the missing critical care time data, which were missing completely at random and included only one time point in four of the time variables. All the ANAM Throughput Scores were normally distributed except for the Simple Reaction Time Throughput, which had a statistically significant negative skew. The Simple Reaction Time Throughput was winsorized with one score changed from 76.62 to 127.14, which corrected the skew.

Physiological Data

Heart Rate, Systolic Blood Pressure, and Diastolic Blood Pressure were normally distributed (See Table 6). Respiratory Rate was positively skewed. Respiratory Rate was transformed to achieve a normal distribution with a square root transformation. Oxygen Saturation was negatively skewed, and a normal distribution could not be achieved with any transformations. The analysis was conducted on the oxygen saturation data as measured because RM ANOVA is considered robust to violations of the assumption of normality.

For the multiple regression analyses, the physiologic data at the altitude condition were averaged. Average Heart Rate at altitude (AHRalt), Average Systolic Blood Pressure at altitude (ASBPalt), Average Diastolic Blood Pressure at altitude (ADBPalt), and Average Respiratory Rate at altitude (ARRalt) were all normally distributed. The Reflected Square Root Transformation of Average Oxygen Saturation at altitude (ASATalt) resulted in a normal distribution.

Covariates

The covariates Fatigue Assessment Scale score and Months in Healthcare Specialty were continuous variables. The Fatigue Assessment Scale was positively skewed. The Fatigue Assessment Scale was transformed to achieve a normal distribution with a square root transformation. Months in Healthcare Specialty had a normal distribution. Critical Care Experience was a dichotomous variable used in the regression analysis.

Table 6 contains all the outcome variables and continuous covariates, the skew measurements and standard errors, transformations that were successful, and corrected skew measurements.

Table 6

Continuous Measures, Skews, Transformations Applied, and Skews After Transformation

Continuous Measure	**Abbreviation**	**Skew**	**SE**	**Trans-formation**	**New Skew**	**New SE**	**New Measure Abbreviation**
Critical Care Score	CCS	-.132	.221				
Critical Care Score Percent	CCP	-.128	.221				
Critical Care Errors and Omission Score	CCE	.308	.221				
Critical Care Reaction Times	CCRT	.053	.084				
ANAM Throughput Scores	TP						
2-choice reaction time	2CRT	-.224	.221				
Code Substitution Delayed Memory	CDD	.315	.221				
Code Substitution Learning	CDS	.195	.221.				
Logical Relations	LRS	.140	.221				
Math Processing	MTH	.337	.221				
Simple reaction time	SRT	-.855	.221	Winsorize one score	.406	.221	SRTT
Heart rate	HR	.122	.111				
Systolic Blood Pressure	SBP	-.155	.111				
Diastolic Blood Pressure	DBP	.028	.111				
Respiratory Rate	RR	.533	.111	Square Root	.156	.125	RRT
Oxygen saturation	SAT	-1.18	.111				
Average Heart Rate at altitude	AHRalt	-.167	.309				
Average Systolic Blood Pressure at altitude	ASBPalt	.190	.309				

Continuous Measure	Abbreviation	Skew	SE	Trans-formation	New Skew	New SE	New Measure Abbreviation
Average Diastolic Blood Pressure at altitude	ADBPalt	.093	.309				
Average Respiratory Rate at altitude	ARRalt	-.071	.309				
Average Oxygen Saturation at altitude	ASATalt	-.780	.309	Reflect and Square Root	.034	.309	ASATTAlt
Fatigues Assessment Scale Score	FAS	.620	.309	Square Root	.194	.309	FAST
Experience (months is specialty)	EXP	.473	.309				

ANALYSES

INTRODUCTION

Analyses of variance with repeated measures were used to address the hypotheses related to the first research question.

Research Question 1 and Hypotheses

Research Question 1, What are the effects of military aircraft noise and altitude-induced hypoxia on cognitive and physiological performance of CCATT personnel during a simulated critical care patient scenario?, was addressed with six hypotheses.

Hypothesis 1A: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise.

Hypothesis 1B: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise.

Hypothesis 1C: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with altitude-induced hypoxia.

Hypothesis 1D: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with altitude-induced hypoxia.

Hypothesis 1E: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise and altitude-induced hypoxia.

Hypothesis 1F: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise and altitude-induced hypoxia.

Hypotheses 1A, 1C, and 1E

To address Hypothesis 1A, 1C, and 1E, a 2 x 2 RM ANOVA was conducted to explore the impact of altitude and noise on cognitive performance as measured by CCS (see Table 7), CCP (see Table 8), CCE (see Table 9), CCRTs (see Table 10) and ANAM TP scores (see Table 11) . As a within-subject factor, there were two levels of altitude, ground oxygen level and cabin altitude oxygen level. The between-subject factor was noise, with two levels, aircraft cabin noise or ambient room noise. The CCS, CCP, and CCE, were calculated from the video-recordings of the simulations for each condition. The ANAM TP scores were measured to reflect performance during that condition at the end of each simulation.

Table 7

Results of RM ANOVA to Examine Effects of Altitude and Noise on Critical Care Score (CCS)

Source	Type III Sum Squares	df	Mean Square	F	Sig.
Altitude	35.208	1	35.208	15.943	<.001
Altitude*Noise	.208	1	.208	.094	.760
Error (altitude)	128.083	58	2.208		
Noise	66.008	1	66.008	5.729	.020
Error (noise)	668.283	58	11.522		

Table 8

Results of RM ANOVA to Examine Effects of Altitude and Noise on Critical Care Score Percent (CCP)

Source	Type III Sum Squares	df	Mean Square	F	Sig.
Altitude	639.408	1	639.408	17.067	<.001
Altitude*Noise	5.208	1	5.208	.139	.711
Error (altitude)	2172.883	58	37.464		
Noise	1171.875	1	1171.875	5.858	.019
Error (noise)	11603.217	58	200.055		

Table 9

Results of RM ANOVA to Examine Effects of Altitude and Noise on Critical Care Errors and Omissions (CCE)

Source	Type III Sum Squares	df	Mean Square	F	Sig.
Altitude	38.533	1	38.533	11.104	.002
Altitude*Noise	1.200	1	1.200	.346	.559
Error (altitude)	201.267	58	3.470		
Noise	64.533	1	64.533	4.129	.047
Error (noise)	906.467	58	15.629		

Table 10

Results of RM ANOVA to Examine Effects of Altitude and Noise on Critical Care Reaction Times (CCRTs)

Measure	Source	Type III Sum Squares	df	Mean Square	F	Sig.
T4	Altitude	.000	1	.000	.001	.973
	Altitude*Noise	.558	1	.558	1.295	.260
	Error (altitude)	24.966	58	.430		
	Noise	1.971	1	1.1971	2.146	.148
	Error (noise)	53.268	58	.918		
T5	Altitude	7.778	1	7.778	.951	.334
	Altitude*Noise	37.666	1	37.666	4.605	.036
	Error (altitude)	474.403	58	8.179		
	Noise	2.228	1	2.228	.146	.704
	Error (noise)	886.975	58	15.293		
T6	Altitude	3.078	1	3.078	4.033	.049
	Altitude*Noise	2.488	1	2.488	3.260	.076
	Error (altitude)	44.267	58	.763		
	Noise	2.730	1	2.730	1.026	.315
	Error (noise)	154.390	58	2.662		
T7	Altitude	.770	1	.770	.422	.578
	Altitude*Noise	2.861	1	2.861	1.570	.215
	Error (altitude)	105.687	58	105.687		
	Noise	.832	1	.832	.157	.694
	Error (noise)	306.931	58	5.292		
T14	Altitude	.668	1	.668	.820	.369
	Altitude*Noise	.211	1	.211	.259	.613
	Error (altitude)	47.201	58	.814		
	Noise	.815	1	.815	.568	.454
	Error (noise)	83.232	58	1.435		
T15	Altitude	.064	1	.064	.120	.731
	Altitude*Noise	8.33E-07	1	8.33E-07	.000	.999
	Error (altitude)	30.986	58	.534		
	Noise	.145	1	.145	.115	.736
	Error (noise)	73.302	58	1.264		
T16	Altitude	1.113	1	1.113	1.632	.206
	Altitude*Noise	1.485	1	1.485	2.143	.149

Error (altitude)	40.191	58	.693		
Noise	.0007	1	.007	.006	.940
Error (noise)	73.985	58	1.276		

Table 11

Results of RM ANOVA to Examine Effects of Altitude and Noise on ANAM Throughput (TP) measures for 2-Choice Reaction time (2CRT), Code Substitution-Delayed Memory (CDD), Code Substitution-Learning (CDS), Logical Relations (LRS), Mathematical Processing (MTH), and Transformed Single-Choice Reaction Time (SRTT)

Measure	Source	Type III Sum Squares	df	Mean Square	F	Sig.
2CRT	Altitude	1.956	1	1.956	.022	.883
	Altitude*Noise	.013	1	.013	.000	.990
	Error (altitude)	5183.680	58	89.374		
	Noise	993.716	1	993.716	2.557	.115
	Error (noise)	22540.814	58	388.635		
CDD	Altitude	4.606	1	4.606	.049	.825
	Altitude*Noise	142.115	1	142.115	1.515	.223
	Error (altitude)	5438.895	58	93.774		
	Noise	96.248	1	96.248	.347	.558
	Error (noise)	16067.749	58	277.030		
CDS	Altitude	2.809	1	2.809	.176	.677
	Altitude*Noise	3.214	1	3.214	.201	.655
	Error (altitude)	926.988	58	15.983		
	Noise	25.743	1	25.743	.152	.698
	Error (noise)	9841.958	58	169.689		
LRS	Altitude	.156	1	.156	.018	.893
	Altitude*Noise	.000	1	.000	.000	.995
	Error (altitude)	500.070	58	8.622		
	Noise	71.719	1	71.719	.752	.389
	Error (noise)	5529.287	58	95.333		
MTH	Altitude	.055	1	.055	.004	.947
	Altitude*Noise	.451	1	.451	.036	.850
	Error (altitude)	729.590	58	12.579		
	Noise	.075	1	.075	.001	.974
	Error (noise)	4131.318	58	71.230		
SRTT	Altitude	259.396	1	259.396	.420	.520
	Altitude*Noise	443.636	1	443.636	.718	.400
	Error (altitude)	35838.371	58	617.903		
	Noise	20.017	1	20.017	.015	.902
	Error (noise)	76450.161	58	1318.106		

Hypothesis 1E: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise and altitude-induced hypoxia.

The interaction effects of noise and altitude were analyzed first for each cognitive outcome variable (See Tables 7-11).

Critical Care Scores

The interaction effect [$F(1, 58) = .094$, $p = .760$] did not reach statistical significance. The effect of noise and altitude on CCS were independent of each other. Figure 6 is a graph of the interaction of noise and altitude on CCS. Hypothesis 1E was not supported.

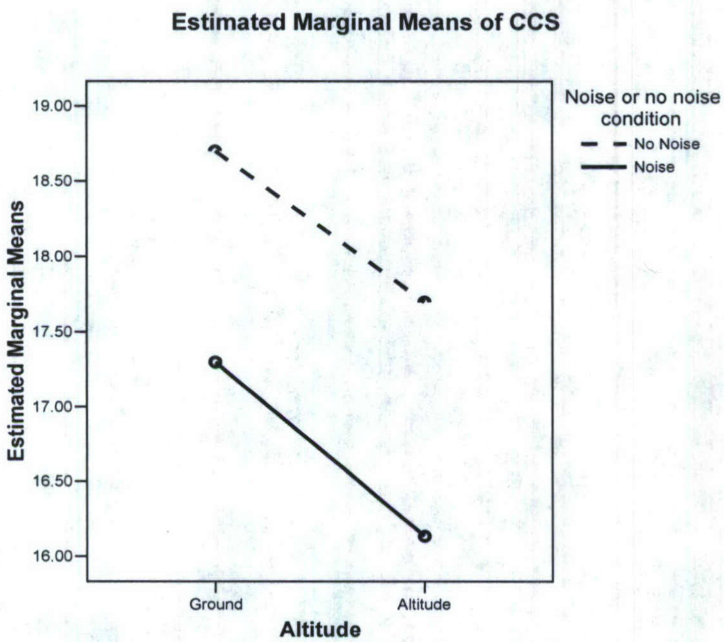

Figure 6. Estimated Marginal Means of Critical Care Score in number of correct actions at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

Critical Care Score Percent

The interaction effect [$F(1, 58) = .139$, $p = .711$] did not reach statistical significance. The effect of noise and altitude on CCP were independent of each other. Figure 7 is a graph of the interaction of noise and altitude on CCP. Hypothesis 1E was not supported.

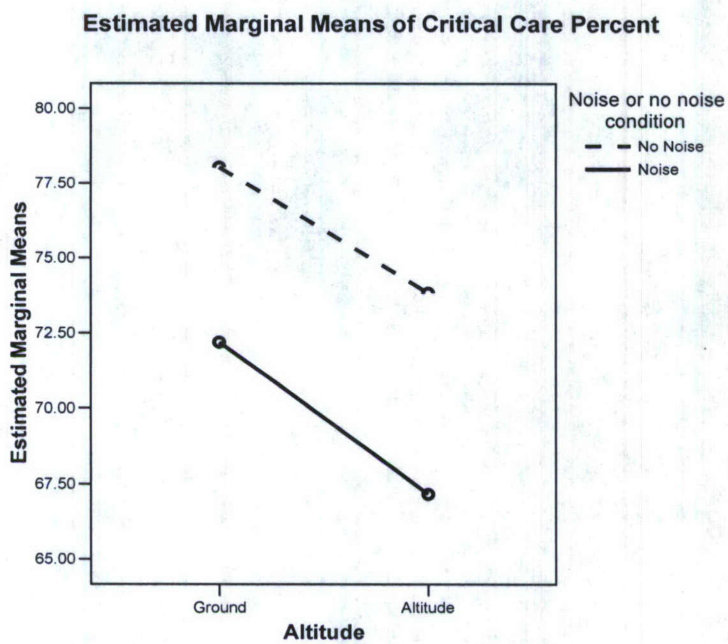

Figure 7. Estimated marginal means of Critical Care Score Percent at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

Critical Care Errors and Omissions

The interaction effect [$F(1, 58) = .346$, $p = .559$] did not reach statistical significance. The effects of noise and altitude on CCE were independent of each other. Figure 8 is a graph of the interaction of noise and altitude on CCE. Hypothesis 1E was not supported.

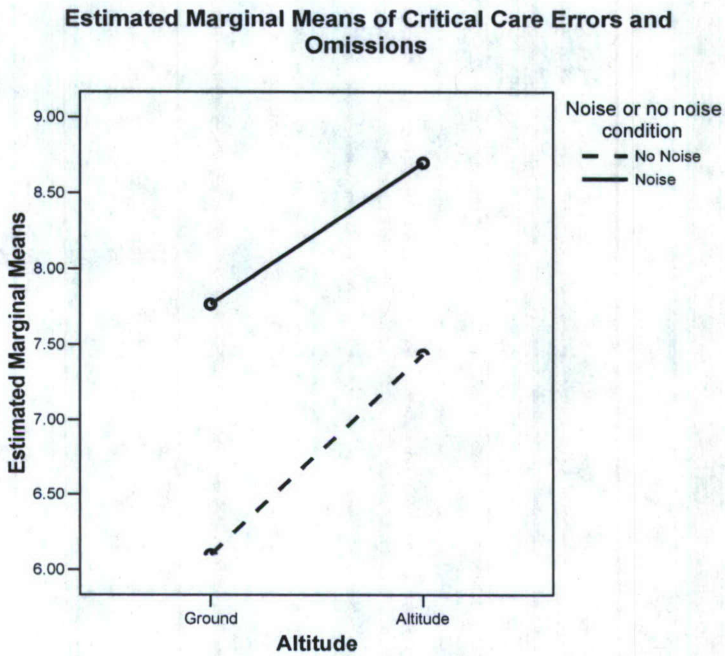

Figure 8. Estimated Marginal Means of Critical Care Errors and Omissions in number of incorrect actions and omissions at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

Critical Care Reaction Times

The interaction of noise and altitude on CCRT5, Hangs IV fluids, was statistically significant [$F(1, 58) = 4.605$, $p = .036$]. At altitude with noise, CCRT5 was lower [M = 4.15, SD = 3.22] than at altitude with no noise [M = 4.99. SD = 3.68]. At ground with noise, CCRT 5 was higher [M = 5.78, SD = 3.77] than at ground with no noise [M = 4.39, SD = 2.96]. The interaction of noise and altitude on CCRT6, Starts BVM breathing, approached statistical significance [$F(1, 58) = 3.26$, $p = .076$]. At altitude with noise CCRT6 was lower [M = 4.21, SD = 1.10] than at altitude with no noise [M = 4.79, SD = 1.41]. At ground with noise, CCRT6 was similar [M = 4.17, SD = 1.7] to at ground with no noise [M = 4.19, SD = 1.51]. The interactions for the remaining CCRTs were not statistically significant (See Table 10). The effect of noise and altitude on CCRT 4, 7, 14, 15, and 16 were independent of each other. Figures 9 through 15 are graphs of the interaction of noise and altitude on CCRTs. Hypothesis 1E was supported for CCRT 5 and 6. Hypothesis 1E was not supported for CCRT 4, 7, 14, 15, and 16.

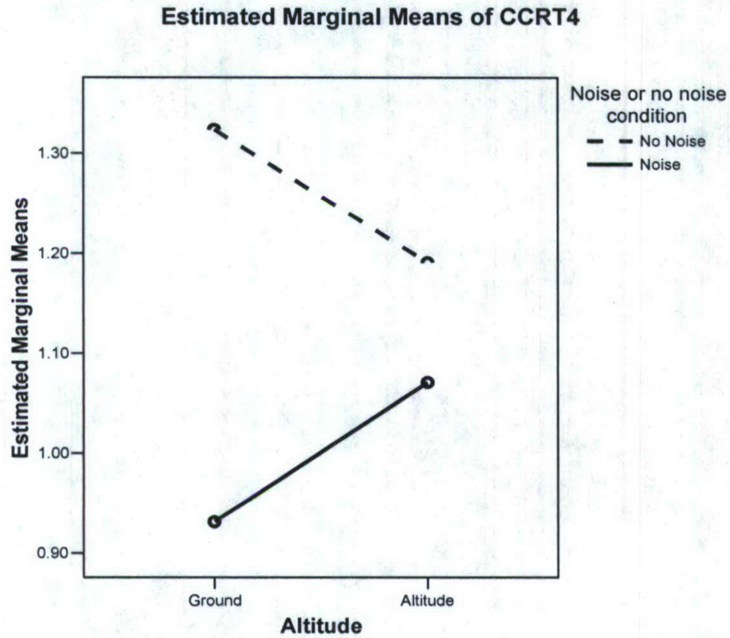

Figure 9. Estimated Marginal Means of Critical Care Reaction Time 4 in minutes (Puts on oxygen) at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

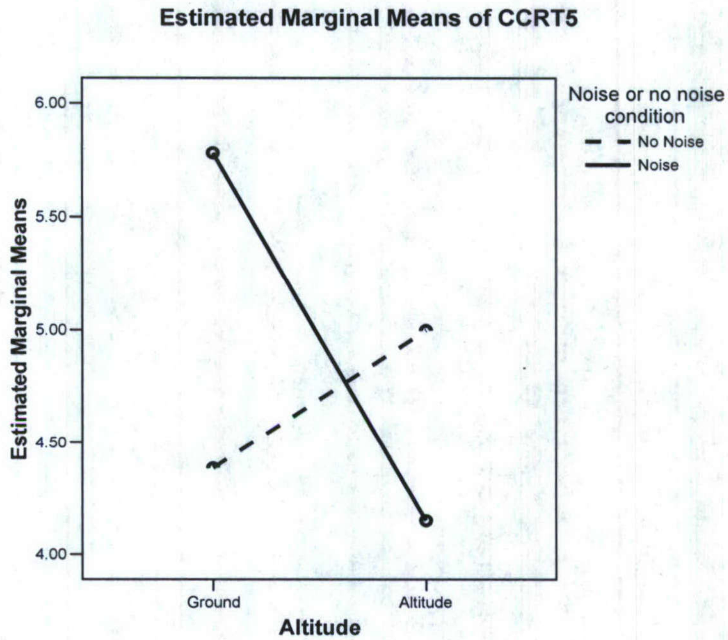

Figure 10. Estimated Marginal Means of Critical Care Reaction Time 5 in minutes (Hangs IV fluids) at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

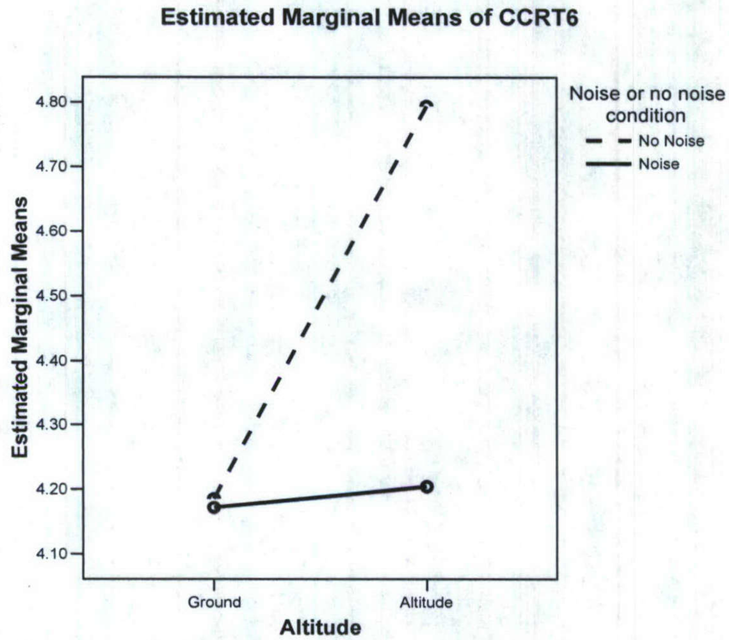

Figure 11. Estimated Marginal Means of Critical Care Reaction Time 6 in minutes (Starts BVM breathing) at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

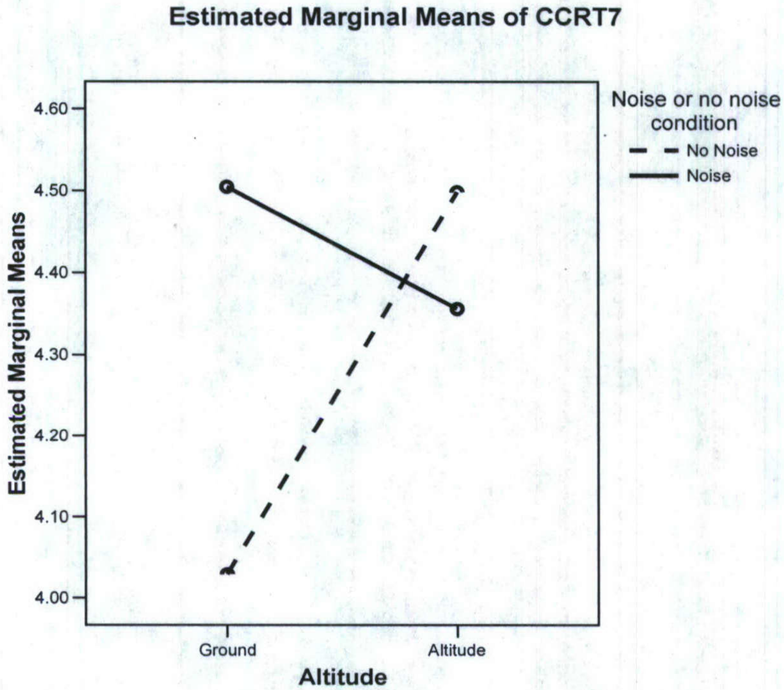

Figure 12. Estimated Marginal Means of Critical Care Reaction Time 7 in minutes (Intubates/advanced airway) at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

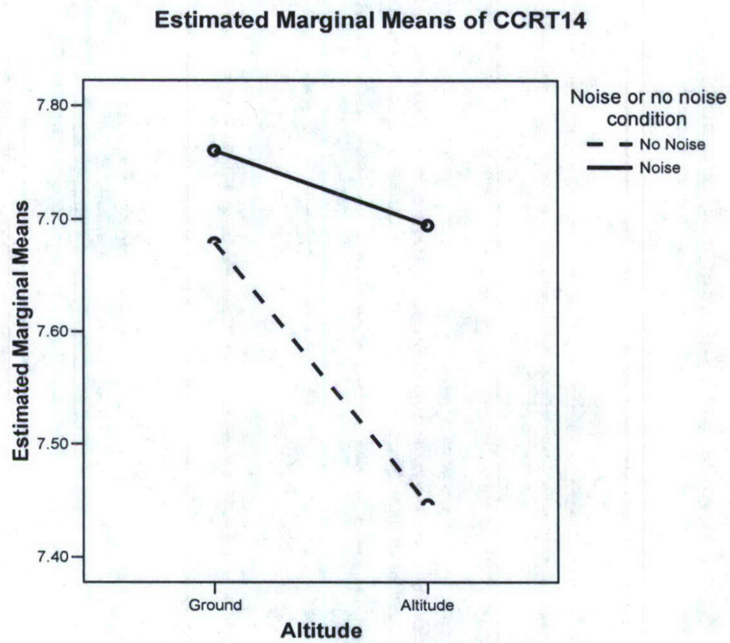

Figure 13. Estimated Marginal Means of Critical Care Reaction Time 14 in minutes (Defibrillates 1st time) at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

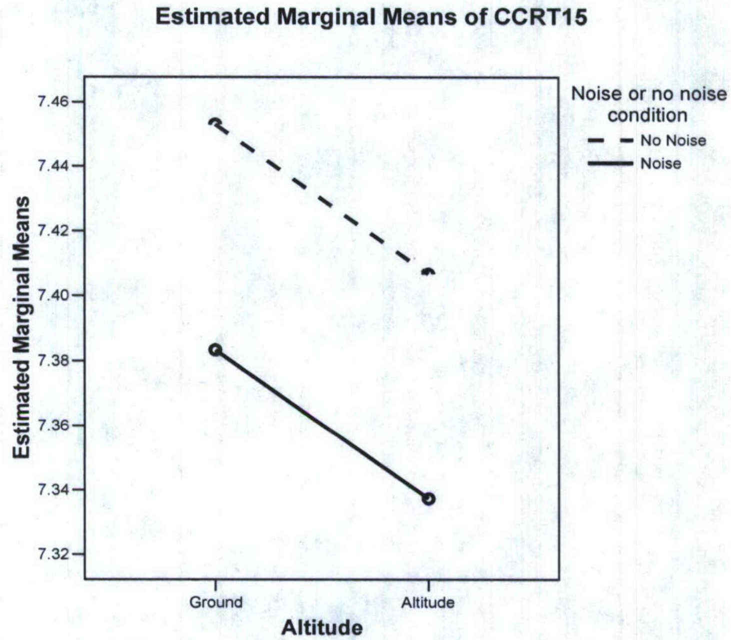

Figure 14. Estimated Marginal Means of Critical Care Reaction Time 15 in minutes Gives epinephrine 1 mg or Vasopressin 40 U IV) at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

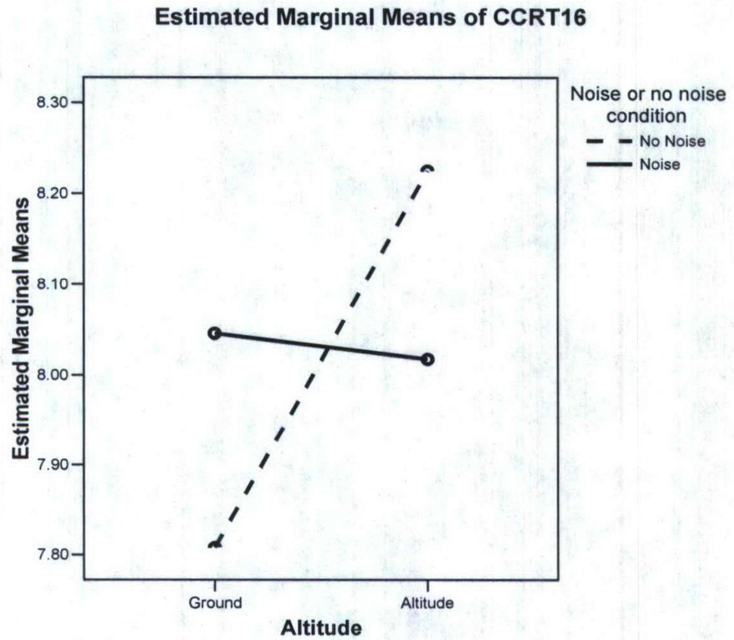

Figure 15. Estimated Marginal Means of Critical Care Reaction Time 16 in minutes (Gives Amiodarone 300 mg IV or Lidocaine 1.5 mg/kg IV) at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

ANAM Throughput Scores

For analysis of the six ANAM Throughput Scores with RM ANOVA, the interaction effects did not reach statistical significance. The effects of noise and altitude on ANAM TP were independent of each other. Hypothesis 1E was not supported.

Summary of Results for Hypothesis 1E

The interaction effects of noise and altitude were analyzed first for each cognitive outcome variable. The interaction of noise and altitude did not make a statistically significant difference in cognitive performance as measured by CCS, CCP, and CCE. Hypothesis 1E was not supported by these results. CCRT5 had statistically significant interaction effects with noise and altitude, and the interaction effects approached significance for CCRT6. At altitude, reaction time decreased with noise for both CCRTs 5 and 6. At ground, reaction time increased with noise for CCRT 5, and was unchanged for CCRT6. Hypothesis 1E was supported by the results of the effects of the interaction of noise and altitude on CCRTs 5 and 6.

Hypothesis 1A: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise.

The main effects of noise on the cognitive variables were analyzed.

Critical Care Scores

There was a statistically significant difference in CCSs for noise [F(1, 58) = 5.729, p = .020]. Average CCSs were lower at the high noise (M = 16.717, SD = 3.79) than at the low noise (M = 18.20, SD = 3.79) conditions. Hypothesis 1A was supported.

Critical Care Score Percent

There was a statistically significant difference in CCPs for noise [F(1, 58) = 5.858, p = .019]. Average CCPs were lower at the high noise (M = 69.683, SD = 14.15) than at the low noise (M = 75.993, SD = 14.15) conditions. Hypothesis 1A was supported.

Critical Care Errors and Omissions

There was a statistically significant difference in CCEs for noise [F(1, 58) = 4.129, p = .047]. Average CCEs were higher at the high noise (M = 8.233, SD = 3.95) than at the low noise (M = 6.767, SD = 3.95) conditions. Hypothesis 1A was supported.

Critical Care Reaction Times

There was no statistically significant difference in CCRT4 for noise [$F(1, 58) = 2.146$, $p = .148$]. Average CCRT4 was similar at the high noise ($M = 1.001$, $SD = .961$) and at the low noise ($M = 1.257$, $SD = .961$) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in CCRT5 for noise [$F(1, 58) = .146$, $p = .704$]. Average CCRT5 was similar at the high noise ($M = 4.966$, $SD = 4.26$) and at the low noise ($M = 4.694$, $SD = 4.26$) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in CCRT6 for noise [$F(1, 58) = 1.026$, $p = .315$]. Average CCRT6 was similar at the high noise ($M = 4.188$, $SD = 1.63$) and at the low noise ($M= 4.490$, $SD = 1.63$) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in CCRT7 for noise [$F(1, 58) = .157$, $p = .693$]. Average CCRT7 was similar at the high noise ($M = 4.430$, $SD = 2.30$) and at the low noise ($M= 4.264$, $SD = 2.30$) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in CCRT14 for noise [$F(1, 58) = .568$, $p = .454$]. Average CCRT14 was similar at the high noise ($M = 7.828$, $SD = 1.20$) and at the low noise ($M= 7.563$, $SD = 1.20$) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in CCRT15 for noise [F(1, 58) = .115, p = .736]. Average CCRT15 was similar at the high noise (M = 7.36, SD = 1.12) and at the low noise (M= 7.43, SD = 1.12) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in CCRT16 for noise [F(1, 58) = .006, p = .940]. Average CCRT16 was similar at the high noise (M = 8.032, SD = 1.13) and at the low noise (M= 8.016, SD = 1.13) conditions. Hypothesis 1A was not supported.

ANAM Throughput Scores

There was no statistically significant difference in 2-Choice Reaction Time Throughput (2CRT TP) for noise [F(1, 58) = 2.557, p = .115]. Average 2CRT TP was similar at the high noise (M = 134.198, SD = 19.72) and at the low noise (M = 139.953, SD = 19.72) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in Code Substitution Delayed Memory Throughput (CDD TP) for noise [F(1, 58) = .347, p = .558]. Average CDD TP was similar at the high noise (M = 38.946, SD = 16.65) and at the low noise (M = 40.738, SD = 16.65) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in Code Substitution Learning Throughput (CDS TP) for noise [F(1, 58) = .152, p = .698]. Average CDS TP was similar at the high noise (M = 47.076, SD = 12.4) and at the low noise (M = 48.002, SD = 12.4) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in Logical Relations Throughput (LRS TP) for noise [F(1, 58) = .752, p = .389]. Average LRS TP was similar at the high noise (M = 26.437, SD = 9.77) and at the low noise (M = 27.983, SD = 9.77) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in Mathematical Processing Throughput (MTH TP) for noise [F(1, 58) = .001, p = .974]. Average MTH TP was similar at the high noise (M = 24.778, SD = 8.45) and at the low noise (M = 24.828, SD = 8.45) conditions. Hypothesis 1A was not supported.

There was no statistically significant difference in the transformed Single Reaction Time Throughput (SRRT TP) for noise [F(1, 58) = .015, p = .902]. Average SRRT TP was similar at the high noise (M = 220.226, SD = 36.32) and at the low noise (M = 221.043, SD = 36.32) conditions. Hypothesis 1A was not supported.

Summary of Results for Hypothesis 1A

The effects of noise were analyzed for each cognitive outcome variable. Noise significantly negatively impacted Critical Care Score, Critical Care Percent, and Critical Care Errors and Omissions Score. Critical Care Score and Critical Care Percent were lower with high noise. There were significantly more Errors and Omissions occurring in the higher noise condition. These results support Hypothesis 1A. Noise did not have an effect on Critical Care Reaction Times or performance on any of the tests in the cognitive battery. Hypothesis 1A was supported for CCS, CCP and CCE. Hypothesis 1A was not supported for the CCRTs or ANAM TP measures.

Hypothesis 1C: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with altitude-induced hypoxia.

The main effects of altitude on the cognitive variables were analyzed.

Critical Care Scores

For analysis with a RM ANOVA, there was a statistically significant difference in CCS for altitude [$F(1, 58) = 15.943$, $p < .001$]. Average CCS was lower at the high altitude ($M = 16.917$, $SD = 2.56$) than at the low altitude ($M = 18.00$, $SD = 2.68$) conditions. Hypothesis 1C was supported.

Critical Care Score Percent

For analysis with a RM ANOVA, there was a statistically significant difference in CCP for altitude [$F(1, 58) = 17.067$, $p < .001$]. Average CCP was lower at the high altitude ($M = 70.50$, $SD = 10.13$) than at the low altitude ($M = 75.117$, $SD = 11.07$) conditions. Hypothesis 1C was supported.

Critical Care Errors and Omissions

For analysis with a RM ANOVA, there was a statistically significant difference in CCE for altitude [$F(1, 58) = 11.104$, $p = .002$]. Average CCE was higher at the high altitude ($M = 8.067$, $SD = 2.97$) than at the low altitude ($M = 6.933$, $SD = 3.21$) conditions. Hypothesis 1C was supported.

Critical Care Reaction Times

There was no statistically significant difference in CCRT4 for altitude [$F(1, 58) = .001$, $p = .973$]. Average CCRT4 was similar at the high altitude ($M = 1.13$, $SD = .81$) and at the low altitude ($M = 1.127$, $SD = .84$) conditions. Hypothesis 1C was not supported.

There was no statistically significant difference in CCRT5 for altitude [$F(1, 58) = .951$, $p = .384$]. Average CCRT5 was similar at the high altitude ($M = 4.58$, $SD = 3.46$)

and at the low altitude (M = 5.09, SD = 3.39) conditions. Hypothesis 1C was not supported.

There was a statistically significant difference in CCRT6 for altitude [F(1, 58) = 4.033, p = .049]. Average CCRT6 was longer at the high altitude (M = 4.5, SD = 1.26) than at the low altitude (M = 4.18, SD = 1.35) conditions. Hypothesis 1C was supported.

There was no statistically significant difference in CCRT7 for altitude [F(1, 58) = .422, p = .518]. Average CCRT7 was similar at the high altitude (M = 4.43, SD = 1.95) and at the low altitude (M = 4.27, SD = 1.81) conditions. Hypothesis 1C was not supported.

There was no statistically significant difference in CCRT14 for altitude [F(1, 58) = .820, p = .369]. Average CCRT14 was similar at the high altitude (M = 7.57, SD = .91) and at the low altitude (M = 7.72, SD = 1.17) conditions. Hypothesis 1C was not supported.

There was no statistically significant difference in CCRT15 for altitude [F(1, 58) = .120, p = .731]. Average CCRT15 was similar at the high altitude (M = 7.37, SD = .97) and at the low altitude (M = 7.42, SD = .92) conditions. Hypothesis 1C was not supported.

There was no statistically significant difference in CCRT16 for altitude [F(1, 58) = 1.632, p = .206]. Average CCRT16 was similar at the high altitude (M = 8.12, SD = 1.08) and at the low altitude (M = 7.93, SD = .90) conditions. Hypothesis 1C was not supported.

ANAM Throughput Scores

There was no statistically significant difference in 2CCRT TP for altitude [F(1, 58) = .022, p = .883]. Average 2CRT TP was similar at the low altitude (M = 136.95, SD = 15.44) and at the high altitude (M = 137.20, SD = 15.49) conditions. Hypothesis 1C was not supported.

There was no statistically significant difference in CDD TP for altitude [F(1, 58) = .049, p = .825]. Average CDD TP was similar at the low altitude (M = 39.65, SD = 13.43) and at the high altitude (M = 40.04, SD = 13.82) conditions. Hypothesis 1C was not supported.

There was no statistically significant difference in CDS TP for altitude [F(1, 58) = .176, p = .677]. Average CDS TP was similar at the low altitude (M = 47.39, SD = 9.59) and at the high altitude (M = 47.69, SD = 9.69) conditions. Hypothesis 1C was not supported.

There was no statistically significant difference in LRS TP for altitude [F(1, 58) = .018, p = .893]. Average LRS TP was similar at the low altitude (M = 27.174, SD = 7.07) and at the high altitude (M = 27.246, SD = 7.36) conditions. Hypothesis 1C was not supported.

There was no statistically significant difference in MTH TP for altitude [F(1, 58) = .004, p = .947]. Average MTH TP was similar at the low altitude (M = 24.782, SD = 6.386) and at the high altitude (M = 24.825, SD = 6.56) conditions. Hypothesis 1C was not supported.

There was no statistically significant difference in SRTT TP for altitude [F(1, 58) = .420, p = .520]. Average SRTT TP was similar at the low altitude (M = 219.16, SD =

31.26) and at the high altitude (M = 222.10, SD = 31.0) conditions. Hypothesis 1C was not supported.

Summary of Results for Hypothesis 1C

The effects of altitude were analyzed for each cognitive outcome variable. Altitude made a significance difference in Critical Care Score and Critical Care Percent, where increased altitude resulted in decreased scores and percent. Altitude also negatively impacted errors and omissions in a statistically significant manner, with the number of errors and omissions increasing with higher altitude. CCRT6 was also significantly impacted by altitude, with an increase in reaction time found at higher altitude. These results all support Hypothesis 1C. Altitude had no measurable effect on performance of the ANAM4 tests, or the Critical Care Reaction Times other than CCRT6. Hypothesis 1C was supported for CCS, CCP, CCE, and CCRT6. Hypothesis 1C was not supported for the CCRTs 4, 5, 7, 14, 15, 16, or the ANAM TP measures.

Hypotheses 1B, 1D, and 1F

To address Hypothesis 1B, 1D, and 1F, a 2 x 2 x 4 RM ANOVA was conducted to explore the impact of altitude, noise, and time on physiological performance as measured by Heart Rate (see Table 12), Systolic Blood Pressure (see Table 13), Diastolic Blood Pressure (see Table 14), Respiratory Rate Transformed (RRT) (see Table 15), and Oxygen Saturation (Table 16). A within-subject factor was altitude, with two levels, ground oxygen level and cabin altitude oxygen level. Another within-subject factor was time, with four measurements taken during each 20-minute critical care scenario. The between-subject factor was noise with two levels, aircraft cabin noise or ambient room noise. Time was a design element included in the analysis to capture within subject variability and was not a component of the hypotheses tests.

Table 12

Results of RM ANOVA to Examine Effects of Altitude, Noise, and Time on HR

Source	Type III Sum Squares	df	Mean Square	F	Sig.
Altitude	3065.352	1	3065.352	34.260	<.001
Altitude*Noise	191.269	1	191.269	2.138	.149
Error (Altitude)	5189.504	58	89.474		
Time	3274.49	3	1091.497	18.765	<.001
Time*Noise	81.423	3	27.141	.467	.706
Error (Time)	10120.962	174	58.166		
Altitude*time	34.406	3	11.469	.237	.870
Altitude*Time*Noise	178.323	3	59.441	1.2028	.301
Error (alt*time)	8420.646	174	48.395		
Noise	850.669	1	850.669	.914	.343
Error (noise)	53973.854	58	930.584		

Table 13

Results of RM ANOVA to Examine Effects of Altitude, Noise, and Time on SBP

Source	Type III Sum Squares	df	Mean Square	F	Sig.
Altitude	53.333	1	53.333	.116	.735
Altitude*Noise	29.008	1	29.008	.063	.803
Error (Altitude)	26769.158	58	461.537		
Time	2823.95	3	941.317	2.531	.059
Time*Noise	583.942	3	194.647	.523	.667
Error (Time)	64707.608	174	371.883		
Altitude*time	168.650	2.5078	65.431	.126	.924
Altitude*Time*Noise	2093.275	3	697.758	1.565	.200
Error (alt*time)	77592.575	174	445.934		
Noise	2755.208	1	2755.208	2.228	.137
Error (noise)	70159.658	58	1209.649		

Table 14

Results of RM ANOVA to Examine Effects of Altitude, Noise, and Time on DBP

Source	Type III Sum Squares	df	Mean Square	F	Sig.
Altitude	81.675	1	81.675	.283	.597
Altitude*Noise	44.408	1	44.408	.154	.696
Error (Altitude)	16755.917	58	288.895		
Time	2521.517	2.630	958.913	3.125	.034
Time*Noise	263.750	3	87.917	.327	.806
Error (Time)	46805.733	174	268.99		
Altitude*time	129.608	2.531	51.202	.166	.892
Altitude*Time*Noise	981.275	3	327.092	1.259	.290
Error (alt*time)	45198.117	174	259.759		
Noise	504.300	1	504.300	.684	.411
Error (noise)	42735.167	58	736.813		

Table 15

Results of RM ANOVA to Examine Effects of Altitude, Noise, and Time on RRT

Source	Type III Sum Squares	df	Mean Square	F	Sig.
Altitude	11.576	1	11.576	74.256	<.001
Altitude*Noise	.007	1	.007	.045	.833
Error (Altitude)	9.042	58	.157		
Time	.398	3	.133	.439	.725
Time*Noise	.402	3	.134	.443	.723
Error (Time)	56.60	174	.302		
Altitude*time	.758	3	.253	1.059	.368
Altitude*Time*Noise	.296	3	.099	.414	.743
Error (alt*time)	41.507	174	.239		
Noise	1.944	1	1.944	5.817	.019
Error (noise)	19.379	58	.334		

Table 16

Results of RM ANOVA to Examine Effects of Altitude, Noise, and Time on SAT

Source	Type III Sum Squares	df	Mean Square	F	Sig.
Altitude	3569.752	1	3569.752	398.455	<.001
Altitude*Noise	2.002	1	2.002	.223	.638
Error (Altitude)	519.621	58	8.959		
Time	21.506	3	7.169	2.14	.097
Time*Noise	2.24	3	.747	.223	.880
Error (Time)	582.879	174	3.350		
Altitude*time	16.756	3	5.585	1.748	.159
Altitude*Time*Noise	.273	3	.091	.028	.994
Error (alt*time)	556.096	174	3.196		
Noise	.102	1	.102	.009	.923
Error (noise)	633.304	58	10.919		

Hypothesis 1F: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise and altitude-induced hypoxia.

The interactions of noise, altitude, and time were analyzed.

Heart Rate

The interaction effects of altitude and noise [F(1, 58) = 2.138, p = .149] on Heart Rate (HR) did not reach statistical significance. The effects of altitude and noise on HR were independent of each other. Hypothesis 1F was not supported.

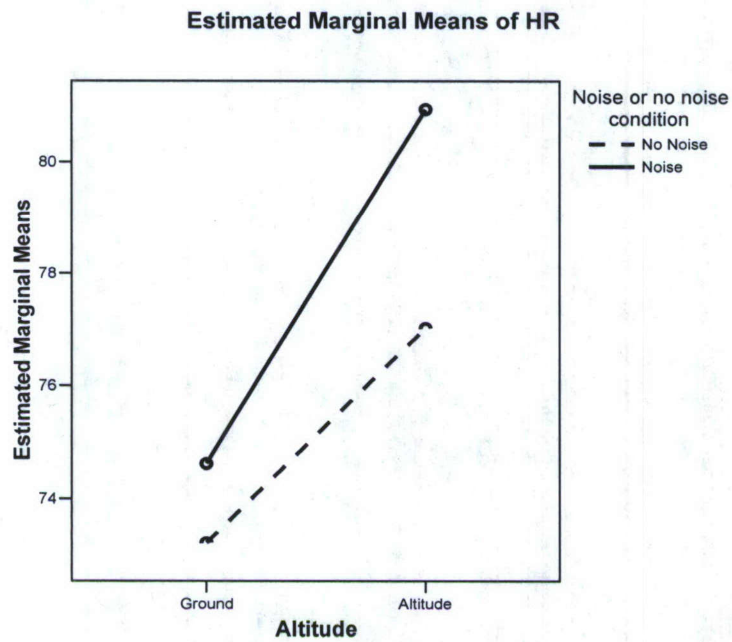

Figure 16. Estimated Marginal Means of Heart Rate in beats per minute at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

The interaction effects of time and noise [F(3, 174) = .223, p = .880] on HR did not reach statistical significance. The effects of time and noise on HR were independent of each other. Mauchely's test indicated corrections were not necessary. The interaction effects of altitude and time [$F(3, 174) = .237$, $p = .870$] on HR did not reach statistical significance. The effects of altitude and time on HR were independent of each other. The interaction effects of altitude, time, and noise [$F(3, 174) = 1.228$, $p = .301$] on HR did not reach statistical significance. The effects of altitude, time, and noise on HR were independent of each other.

Systolic Blood Pressure

The interaction effects of altitude and noise [$F(1, 58) = .063$, $p = .803$] on SBP did not reach statistical significance. The effects of altitude and noise on SBP were independent of each other. Hypothesis 1F was not supported.

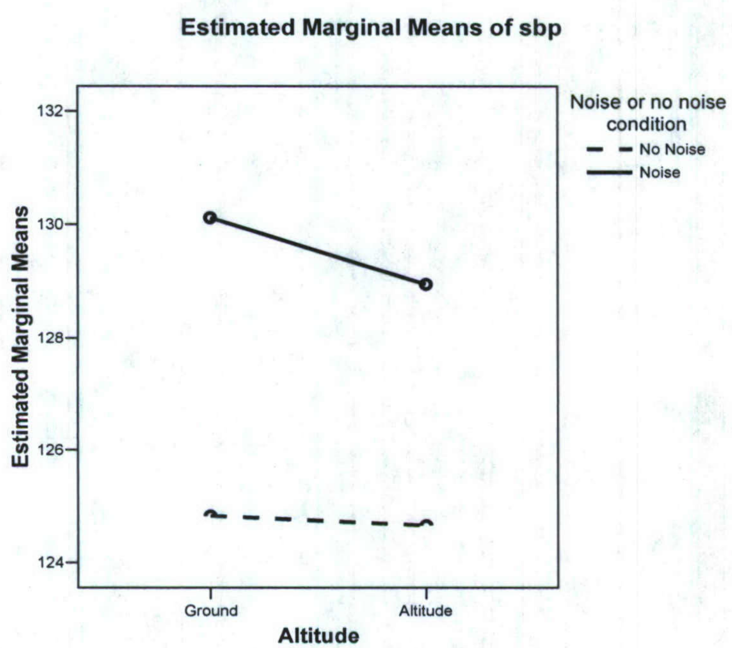

Figure 17. Estimated Marginal Means of Systolic Blood Pressure in mm Hg at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

The interaction effects of time and noise [$F(3, 174) = .523$, $p = .667$] on SBP did not reach statistical significance. The effects of time and noise on SBP were independent of each other. For the altitude and time interaction, Mauchely's test indicated that the assumption of sphericity had been violated ($\chi^2(5) = 12.61$, $p = .027$); therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .801$). The interaction effects of altitude and time [$F(2.578, 174) = .126$, $p = .924$] on SBP did not reach statistical significance. The effects of altitude and time on SBP were independent of each other. Interactions of altitude and noise with time were examined. The interaction effects of altitude, time, and noise [$F(3, 174) = 1.565$, $p = .200$] on SBP did not reach statistical significance. The effects of altitude, time, and noise on SBP were independent of each other.

Diastolic Blood Pressure

The interaction effects of altitude and noise [$F(1, 58) = .154$, $p = .696$] on DBP did not reach statistical significance. The effects of altitude and noise on DBP were independent of each other. Hypothesis 1F was not supported.

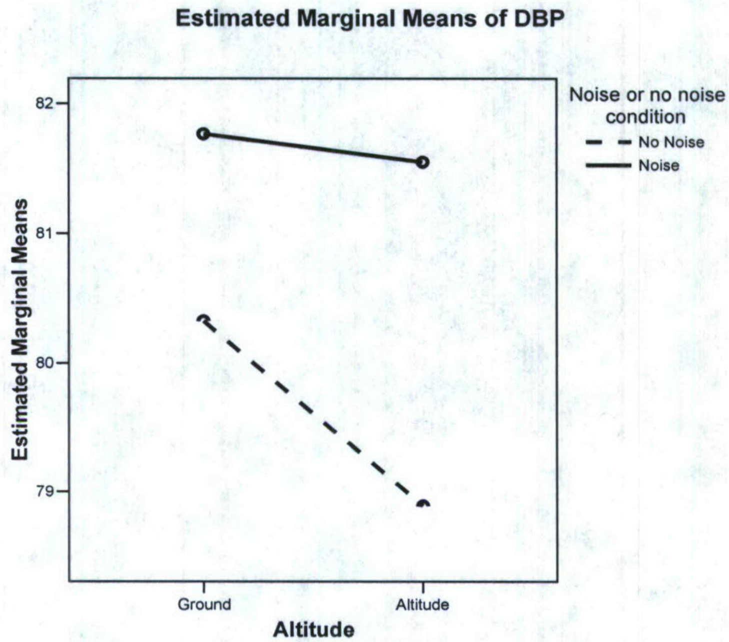

Figure 18. Estimated Marginal Means of Diastolic Blood Pressure in mm Hg at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

For time, Mauchely's test indicated that the assumption of sphericity had been violated ($\chi^2(5) = 15.617$, $p = .008$); therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .759$). The interaction effects of time and noise [$F(3, 174) = .327$, $p = .806$] on DBP did not reach statistical significance. The effects of time and noise on DBP were independent of each other. For the altitude and time interaction, Mauchely's test indicated that the assumption of sphericity had been violated ($\chi^2(5) = 14.784$, $p = .011$); therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .771$). The interaction effects of altitude and time [$F(2.531, 174) = .166$, $p = .892$] on DBP did not reach statistical significance. The effects of altitude and time on DBP were independent of each other. The interaction effects of altitude, time, and noise [$F(3, 174) = 1.259$, $p = .290$] on DBP did not reach statistical significance. The effects of altitude, time, and noise on DBP were independent of each other.

<u>*Respiratory Rate*</u>

The interaction effects of altitude and noise [F(1, 58) = .045, p = .833] on transformed Respiratory Rate (RRT) did not reach statistical significance. The effects of altitude and noise on RRT were independent of each other. Hypothesis 1F was not supported.

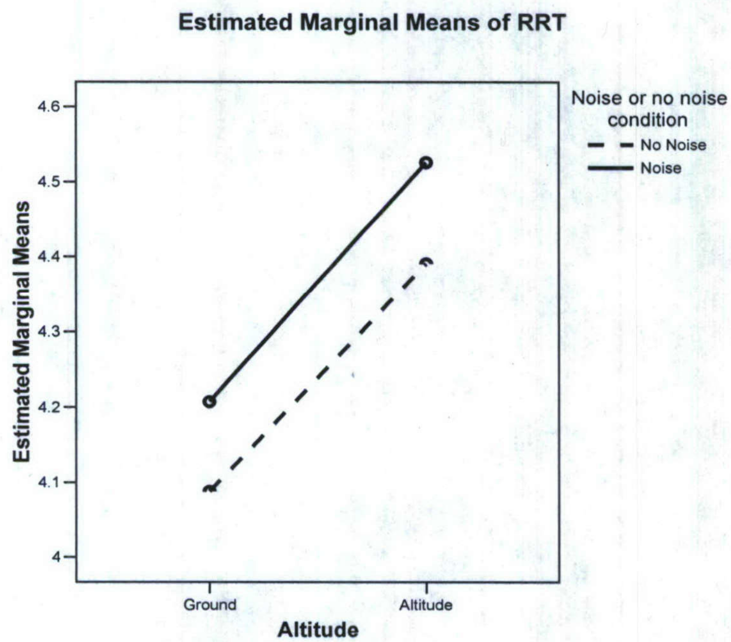

Figure 19. Estimated Marginal Means of Transformed Respiratory Rate in the square root of breaths per minute at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

Mauchley's test indicated corrections were not necessary. The interaction effects of time and noise [F(3, 174) = .443, p = .723] on RRT did not reach statistical significance. The effects of time and noise on RRT were independent of each other. The interaction effects of altitude and time [F(3, 174) = 1.059, p = .368] on RRT did not reach statistical significance. The effects of altitude and time on RRT were independent of each other. The interaction effects of altitude, time, and noise [F(3, 174) = .414, p = .743] on RRT did not reach statistical significance. The effects of altitude, time, and noise on RRT were independent of each other.

Oxygen saturation

The interaction effects of altitude and noise [F(1, 58) = .223, p = .638] on Oxygen Saturation (SAT) did not reach statistical significance. The effects of altitude and noise on SAT were independent of each other. Hypothesis 1F was not supported.

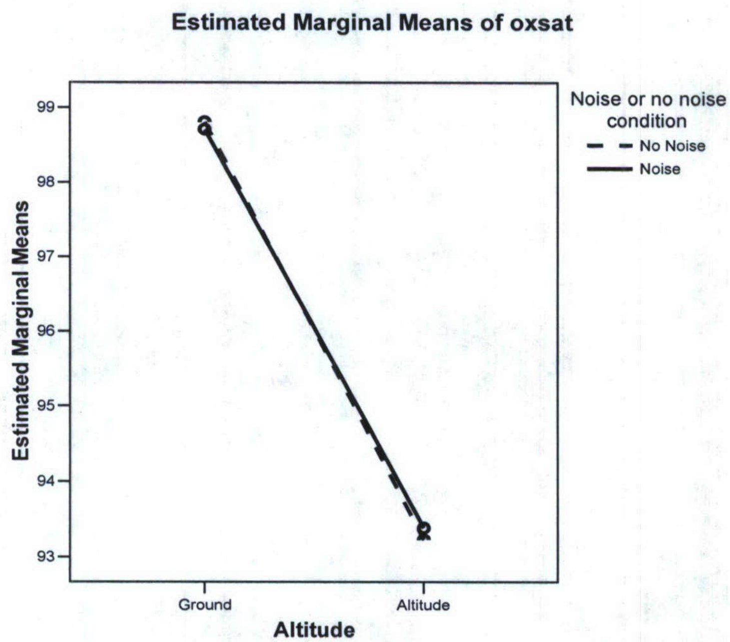

Figure 20. Estimated Marginal Means of Percentage of Oxygen Saturation at ground and cabin altitude for Ambient Noise (No Noise) and Aircraft Cabin Noise (Noise)

Mauchley's test indicated corrections were not necessary. The interaction effects of time and noise [F(3, 174) = .223, p = .880] on SAT did not reach statistical significance. The effects of time and noise on SAT were independent of each other. The interaction effects of altitude and time [F(3, 174) = 1.748, p = .159] on SAT did not reach statistical significance. The effects of altitude and time on SAT were independent of each other. The interaction effects of altitude, time, and noise [$F(3, 174) = .028$, $p = .994$] on SAT did not reach statistical significance. The effects of altitude, time, and noise on SAT were independent of each other.

Summary of Results for Hypothesis 1F

The interaction effects of noise and altitude were analyzed first for each physiological outcome variable. The interaction of noise and altitude did not make a statistically significant difference in physiological performance as measured by Heart Rate, Systolic Blood Pressure, Diastolic Blood Pressure, Respiratory Rate Transformed, and Oxygen Saturation. Hypothesis 1 F was not supported. Time did not interact with noise, altitude, or altitude times noise, therefore there were no differences that depended on time.

Hypothesis 1B: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise.

Heart Rate

There was no statistically significant difference in HR for noise [$F(1, 58) = 1.914$, $p = .343$]. Average HR was similar at the high noise ($M = 77.783$, $SD = 15.26$) and at the low noise ($M = 75.121$, $SD = 15.26$) conditions. Hypothesis 1B was not supported.

Systolic Blood Pressure

There was no statistically significant difference in SBP for noise [$F(1, 58) = 2.278$, $p = .137$]. Average SBP was similar at the high noise ($M = 129.538$, $SD = 17.40$)

and at the low noise (M = 124.746, SD = 17.40) conditions. Hypothesis 1B was not supported.

Diastolic Blood Pressure

There was no statistically significant difference in DBP for noise [F(1, 58) = .684, p = .411]. Average DBP was similar at the high noise (M = 81.658, SD = 13.58) and at the low noise (M = 79.608, SD = 13.58) conditions. Hypothesis 1B was not supported.

Respiratory Rate

There was a statistically significant difference in RRT for noise [F(1, 58) = 5.817, p = .019]. Average RRT was higher at the high noise (M = 4.367, SD = .29) than at the low noise (M = 4.239, SD = .29) conditions. Hypothesis 1B was supported.

Oxygen Saturation

There was no statistically significant difference in SAT for noise [F(1, 58) = .009, p = .923]. Average SAT was similar at the high noise (M = 96.046, SD = 1.65) and at the low noise (M = 96.017, SD = 1.65) conditions. Hypothesis 1B was not supported.

Summary of Results for Hypothesis 1B

The effects of noise were analyzed for each physiological outcome variable. Noise had a statistically significant effect on Respiratory Rate Transformed. With noise, RRT was increased. Hypothesis 1B was supported for RRT. The effects of noise did not make a statistically significant difference in physiological performance as measured by Heart Rate, Systolic Blood Pressure, Diastolic Blood Pressure, and Oxygen Saturation. Hypothesis 1 B was not supported by these results.

<u>Hypothesis 1D:</u> Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with altitude-induced hypoxia.

<u>Heart Rate</u>

For analysis of HR with a RM ANOVA, the main effect for altitude was statistically significant [F(1, 58) = 34.260, p < .001]. Average HR was higher at high altitude (M = 78.979, SD = 11.87) than at low altitude (M = 73.925, SD = 10.70). Hypothesis 1D was supported.

<u>Systolic Blood Pressure</u>

For analysis of SBP with a RM ANOVA, the main effect for altitude was not statistically significant [F(1, 58) = .116, p =.735]. Average SBP was similar at high altitude (M = 126.808, SD = 14.99) and at low altitude (M = 127.475, SD = 13.91). Hypothesis 1D was not supported.

<u>Diastolic Blood Pressure</u>

For analysis of DBP with a RM ANOVA, the main effect for altitude was not statistically significant [F(1, 58) = .283, p =.579]. Average DBP was similar at high altitude (M = 80.221, SD = 11.63) and at low altitude (M = 81.046, SD = 11.03). Hypothesis 1D was not supported.

<u>Respiratory Rate</u>

For analysis of RRT with a RM ANOVA, the main effect for altitude was statistically significant [F(1, 58) = 74.256, p < .001]. Average RRT was higher at high altitude (M = 4.458, SD = .23) than at low altitude (M = 4.148, SD = .26). Hypothesis 1D was supported.

Oxygen Saturation

For analysis of SAT with a RM ANOVA, the main effect for altitude was statistically significant [$F(1, 58) = 398.455$, $p < .001$]. Average SAT was lower at high altitude ($M = 93.304$, $SD = 2.20$) than at low altitude ($M = 98.758$, $SD = .36$). Hypothesis 1D was supported.

Summary of Results for Hypothesis 1D

The effect of altitude was analyzed for each physiological outcome variable. Altitude had a statistically significant impact on Heart Rate, Respiratory Rate, and Oxygen Saturation. Heart Rate and Respiratory Rate were higher at high altitude than at low altitude. Oxygen Saturation was lower at high altitude than at low altitude. Hypothesis 1D was supported for HR, RR, and SAT, but not for SBP or DBP.

Summary of Results for Research Question 1

Research Question 1. What are the effects of military aircraft noise and altitude-induced hypoxia on cognitive and physiological performance of CCATT personnel during a simulated critical care patient scenario?

Noise and altitude together significantly interacted to affect cognitive performance as measured by CCRT5 (Hangs IV fluids) and the interaction approached significance for CCRT 6 (Starts BVM breathing). At altitude with noise, CCRT 5 was decreased, and CCRT was unchanged. Both times increased at altitude with ambient noise. Noise and altitude together did not interact to impact cognitive as measured by the remaining Critical Care Reaction Times, Scores, Errors and Omissions, and the ANAM4, and physiological performance was also not affected.

Noise had a statistically significant effect on cognitive performance as measured by Critical Care Score, Critical Care Percent, and Critical Care Errors and Omissions. Critical Care Scores and Critical Care Percent were lower with the aircraft cabin high noise condition than with the ambient noise condition. Critical Care Errors and Omissions were higher with the aircraft cabin high noise condition than the lower ambient noise condition. The other measures of cognitive performance, Critical Care Reaction Times and the ANAM4 neurocognitive tests, were not influenced by noise.

Altitude had a statistically significant effect on cognitive performance as measured by Critical Care Score, Critical Care Percent, and Critical Care Errors and Omissions, and Critical Care Reaction Time 6 (Starts BVM breathing). Critical Care Scores and Critical Care Percent were lower with the aircraft cabin high altitude condition than the low altitude condition. Critical Care Errors and Omissions increased with the aircraft cabin high altitude condition as compared to the low altitude condition. Critical Care Reaction Time 6 was higher with the high altitude condition than the low altitude condition. The other measures of cognitive performance, Critical Care Reaction Times 4, 5, 7, 14, 15, 16, and the ANAM4 neurocognitive tests, were not influenced by altitude.

A summary of the p values for the RM ANOVA for the Critical Care Scores, Critical Care Percents, Critical Care Errors and Omissions, and Critical Care Reaction Times can be found in Table 17. A summary of the effects of noise and altitude on the Critical Care Scores, Critical Care Percents, Critical Care Errors and Omissions, and Critical Care Reaction Times can be found in Table 18. A summary of the p values for the RM ANOVA for the ANAM Throughput Scores can be found in Table 19. A summary of the effects of noise and altitude on the ANAM Throughput Scores can be found in Table 20. A summary of the p values for the physiological variables can be found in Table 21. A summary of the effects of noise and altitude on the physiological variables can be found in Table 22.

Table 17

Summary of RM ANOVA Results for Cognitive Variables: Critical Care Score (CCS), Critical Care Percent (CCP), Critical Care Errors and Omissions (CCE) Critical Care Reaction Times (CCRT)

	CCS	CCP	CCE	CCRT4	CCRT5	CCRT6	CCRT7	CCRT14	CCRT15	CCRT16
Noise	**p = .020**	**p =.019**	**p =.047**	p =.148	p =.704	p =.315	p =.693	p =.454	p =.736	p =.940
Altitude	**p < .001**	**p < .001**	**p =.002**	p =.973	p =.334	**p =.049**	p =.518	p =.369	p =.731	p =.206
Noise*Altitude	p =.760	p =.711	p = .559	p =.260	**p =.036**	**p =.076**	p =.215	p =.613	p =.999	p =.149

Table 18

Summary of Effects of Noise and Altitude on Cognitive Variables: Critical Care Score (CCS), Critical Care Percent (CCP), Critical Care Errors and Omissions (CCE) Critical Care Reaction Times (CCRT)

	CCS High vs. Low	CCP High vs. Low	CCE High vs. Low	CCRT 4 High vs. Low	CCRT5 High vs. Low	CCRT6 High vs. Low	CCRT7 High vs. Low	CCRT14 High vs. Low	CCRT15 High vs. Low	CCRT16 High vs. Low
Noise	<*	<*	>*	<	>	<	>	>	<	>
Altitude	<*	<*	>*	=	<	>*	=	<	=	>
Noise*Altitude	<	<	>	<	<*	=**	<	>	<	<

* = p < .05, ** = p < .10

Table 19

Summary of RM ANOVA Results for Cognitive Variables: ANAM Tests [2Choice Reaction time (2CRT), Code Substitution Delayed Memory (CDD), Code Substitution Learning (CDS), Logical Relations (LRS), Mathematical Processing (MTH) and transformed Single Choice Reaction Time (SRTT)]

	2CRT	CDD	CDS	LRS	MTH	SRTT
Noise	p = .115	p = .558	p = .698	p = .389	p = .974	p = .920
Altitude	p = .883	p = .825	p = .677	p = .893	p = .947	p = .520
Noise*Altitude	p = .990	p = .223	p = .655	p = .995	p = .850	p = .400

Table 20

Summary of RM ANOVA Results for Cognitive Variables: ANAM Tests [2Choice Reaction time (2CRT), Code Substitution Delayed Memory (CDD), Code Substitution Learning (CDS), Logical Relations (LRS), Mathematical Processing (MTH) and transformed Single Choice Reaction Time (SRTT)]

	2CRT High vs. Low	CDD High vs. Low	CDS High vs. Low	LRS High vs. Low	MTH High vs. Low	SRTT High vs. Low
Noise	<	<	<	<	=	<
Altitude	>	>	=	>	=	>

No significance

Table 21

Summary of RM ANOVA Results for Physiologic Variables: Heart Rate (HR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Transformed Respiratory Rate (RRT), and Oxygen Saturation (SAT)

	HR	SBP	DBP	RRT	SAT
Noise	p = .149	p = .137	p = .411	**p = .019**	p = .923
Altitude	**p = <.001**	p = .735	p = .597	**p = <.001**	**p = <.001**
Time	**p = <.001**	**p = .059**	**p = .034**	p = .725	**p = .097**
Noise*Altitude	p = .149	p = .803	p = .696	p = .833	p = .638
Noise*Time	p = .706	p = .667	p = .806	p = .723	p = .880
Altitude*Time	p = .870	p = .924	p = .892	p = .368	p = .159
Noise*Time*Altitude	p = .301	p = .200	p = .290	p = .743	p = .994

Table 22

Summary of Effects of Noise and Altitude on Physiologic Variables: Heart Rate (HR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Transformed Respiratory Rate (RRT), and Oxygen Saturation (SAT)

	HR High vs. Low	SBP High vs. Low	DBP High vs. Low	RRT High vs. Low	SAT High vs. Low
Noise	>	>	>	>*	=
Altitude	>*	<	<	>*	<*

* = p < .05

Research Question 2. What are the effects of fatigue and clinical experience on cognitive and physiological performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia?

Hypothesis 2A: Fatigue and clinical experience predict cognitive performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia.

Hypothesis 2B: Fatigue and clinical experience predict physiological performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia.

Multiple regression analyses were performed to determine the independent contribution of Fatigue Assessment Score, Experience (Months in Specialty), and Type of Current Clinical Experience (Critical Care vs. Other experience) to the variance in each of the cognitive and physiological dependent variables, with noise and altitude.

Hypothesis 2A

To examine the relationship between cognitive performance, Fatigue Assessment Score Transformed (FAST), Months in Specialty (EXP), and Current Critical Care Experience (CCEXP) with noise and altitude, CCS (see Table 23 and 24), CCP (Table 25 and 26), and CCE (Table 27 and 28) were regressed on the three predictor variables. To examine the relationship between cognitive performance, Fatigue Assessment Score Transformed (FAST), Months in Specialty (EXP), and Critical Care Experience (CCEXP) with noise and altitude, CCRT4 (see Table 29 and 30), CCRT5 (Table 31 and 32), CCRT6 (Table 33 and 34), CCRT7 (Table 35 and 36), CCRT14 (Table 37 and 38), CCR15 (Table 39 and 40), and CCRT16 (Table 41 and 42) were regressed on the three predictor variables.

Critical Care Score

A regression analysis of CCS with altitude (CCSAlt) and noise as the three predictors entered simultaneously as one block accounted for 9% of the variance, and was not statistically significant [F (3, 29) = .198, p = .897]. Experience [t (3, 29) = .324, p = .749), Fatigue [t (3, 29) = .624 = .538), and Current Critical Care Experience [t (3, 29) = .419, p = .679] did not contribute significantly to the variance in CCS with altitude.

Table 23

Correlations of Critical Care Score at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCSAlt	EXP	FAST	CCEXP
CCSAlt	1.0	.061	.107	.066
EXP	.061	1.0	.-.046	.042
FAST	.107	-.046	1.0	-.154
CCEXP	.066	.042	-.154	1.0

No significance

CCSAlt = Critical Care Score with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 24

Results of the Regression Analysis Examining the Contributions of Fatigue, Critical Care Experience, and Months in Specialty to Critical Care Score at Altitude with Noise

Variable	CCSAlt Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	.002	.007	.063	.324	.749
FAST	.563	.902	.123	.624	.538
CCEXP	.468	1.118	.082	.419	.679
Adjusted R^2 .090, p = .897					

CCSAlt = Critical Care Score with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Critical Care Percent

A regression analysis of CCP with altitude (CCPAlt) and noise as the three predictors entered simultaneously as one block accounted for 8.8% of the variance, and was not statistically significant [F (3, 29) = .214, p = .886]. Experience [t (3, 29) = .269, p = .790), Fatigue [t (3, 29) = .716 = .480), and Critical Care Experience [t (3, 29) = .364, p = .719] did not contribute significantly to the variance in CCP with altitude.

Table 25

Correlations of Critical Care Percent at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCPAlt	EXP	FAST	CCEXP
CCPAlt	1.0	.049	.127	.052
EXP	.049	1.0	-.046	.042
FAST	.127	-.046	1.0	-.154
CCEXP	.052	.042	-.154	1.0

No significance

CCPAlt = Critical Care Score Percent with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 26

Results of the Regression Analysis Examining the Contributions of Fatigue, Critical Care Experience and Months in Specialty to Critical Care Percent at Altitude with Noise

	CCPAlt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	.008	.030	.052	.269	.790
FAST	2.73	3.81	.141	.716	.480
CCEXP	1.72	4.72	.071	.364	.719

Adjusted R^2 .088, p = .886

CCPAlt = Critical Care Score Percent with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Critical Care Errors and Omissions

A regression analysis of CCE with altitude (CCEAlt) and noise as the three predictors entered simultaneously as one block accounted for 5.1% of the variance, and was not statistically significant [F (3, 29) = .529, p = .666]. Experience [t (3, 29) = -.476, p = .638), Fatigue [t (3, 29) = -.881 = .386), and Critical Care Experience [t (3, 29) = -.893, p = .380] did not contribute significantly to the variance in CCE with altitude.

Table 27

Correlations of Critical Care Errors and Omissions at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCEAlt	EXP	FAST	CCEXP
CCEAlt	1.0	-.090	-.139	-.150
EXP	-.090	1.0	.-.046	.042
FAST	-.139	-.046	1.0	-.154
CCEXP	-.150	.042	-.154	1.0

No significance

CCEAlt = Critical Care Errors and Omissions with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 28

Results of the Regression Analysis Examining the Contributions of Fatigue, Months in Specialty, and Critical Care Experience to Critical Care Errors and Omissions at Altitude with Noise

	CCEAlt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	-.004	.008	-.091	-.476	.638
FAST	-.916	1.040	-.170	.881	.386
CCEXP	-1.150	1.288	-.172	-.893	.380

Adjusted R^2 .051, p = .666

CCEAlt = Critical Care Errors and Omissions with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Critical Care Reaction Times

A regression analysis of CCRT4 with altitude (CCRT4Alt) and noise as the three predictors entered simultaneously as one block accounted for 5.9% of the variance, and was not statistically significant [F (3, 29) = .463, p = .710]. Experience [t (3, 29) = .715, p = .481], Fatigue [t (3, 29) = -.864 = .395], and Critical Care Experience [t (3, 29) = -.443, p = .661] did not contribute significantly to the variance CCRT4 with altitude.

Table 29

Correlations of Critical Care Reaction Time 4 at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCRT4Alt	EXP	FAST	CCEXP
CCRT4Alt	1.0	.141	-.160	-.054
EXP	.141	1.0	-.046	.042
FAST	-.160	-.046	1.0	-.154
CCEXP	-.054	.042	-.154	1.0

No significance

CCRT4Alt = Critical Care Reaction Time 4 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 30

Results of the Regression Analysis Examining the Contributions of Fatigue, Months in Specialty and Critical Care Experience to Critical Care Reaction Time 4 at Altitude with Noise

	CCRT4Alt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	.001	.002	.137	.715	.481
FAST	-.225	.260	-.167	-.864	.395
CCEXP	-.143	.323	-.086	-.443	.661
Adjusted R^2 .059, p = .710					

CCRT4Alt = Critical Care Reaction Time 4 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

A regression analysis of CCRT5 with altitude (CRRT5Alt) and noise as the three predictors entered simultaneously as one block accounted for 4.3% of the variance, and was not statistically significant [F (3, 29) = .602, p = .619]. Experience [t (3, 29) = -.989, p = .332], Fatigue [t (3, 29) = -.404 = .690], and Critical Care Experience [t (3, 29) = .802, p = .430] did not contribute significantly to the variance in CCRT5 with altitude.

Table 31

Correlations of Critical Care Reaction Time 5 at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCRT5Alt	EXP	FAST	CCEXP
CCRT5Alt	1.0	-.178	-.093	.158
EXP	-.178	1.0	-.046	.042
FAST	-.093	-.046	1.0	-.154
CCEXP	.158	.042	-.154	1.0

No significance

CCRT5Alt = Critical Care Reaction Time 5 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 32

Results of the Regression Analysis Examining the Contributions of Fatigue, Months in Specialty and Critical Care Experience to Critical Care Reaction Time 5 at Altitude with Noise

	CCRT5Alt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	-.010	.010	-.188	-.989	.332
FAST	-.496	1.228	-.078	-.404	.690
CCEXP	1.221	1.521	.154	.802	.430

Adjusted R^2 .043, p = .619

CCRT5Alt = Critical Care Reaction Time 5 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

A regression analysis of CCRT6 with altitude (CCRT6Alt) and noise as the three predictors entered simultaneously as one block accounted for 10.5% of the variance, and was not statistically significant [F (3, 29) = 2.136, p = .120]. Experience [t (3, 29) =

1.965, p = .060], Fatigue [t (3, 29) = -.141 = .170], and Critical Care Experience [t (3, 29) = .265, p = .793] did not contribute significantly to the variance in CCRT6 with altitude.

Table 33

Correlations of Critical Care Reaction Time 6 at Altitude with Noise, Months in Specialty (EXP), Fatigue Assessment Score Transformed, and Critical Care Experience

	CCRT6Alt	EXP	FAST	CCEXP
CCRT6Alt	1.0	.359*	-.274	.100
EXP	.359*	1.0	-.046	.042
FAST	-.274	-.046	1.0	-.154
CCEXP	.100	.042	-.154	1.0

*p = .026

CCRT6Alt = Critical Care Reaction Time 6 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 34

Results of the Regression Analysis Examining the Contributions of Fatigue, Months in Specialty, and Critical Care Experience to Critical Care Reaction Time 6 at Altitude with Noise

	CCRT6Alt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	.006	.003	.346	1.965	.060
FAST	-.546	.387	-.251	-1.410	.170
CCEXP	.127	.479	.047	.265	.793

Adjusted R^2 .105, p = .120

CCRT6Alt = Critical Care Reaction Time 6 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

A regression analysis of CCRT7 with altitude (CCRT7Alt) and noise as the three predictors entered simultaneously as one block accounted for 4.0 % of the variance, and was not statistically significant [F (3, 29) = .629, p = .603]. Experience [t (3, 29) = .889, p = .382], Fatigue [t (3, 29) = .792 = .436], and Critical Care Experience [t (3, 29) = -.628, p = .535] did not contribute significantly to the variance in CCRT7 with altitude.

Table 35

Correlations of Critical Care Reaction Time 7 at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCRT7Alt	EXP	FAST	CCEXP
CCRT7Alt	1.0	.157	.163	-.137
EXP	.157	1.0	-.046	.042
FAST	.163	-.046	1.0	-.154
CCEXP	-.137	.042	-.154	1.0

No significance

CCRT7Alt = Critical Care Reaction Time 7 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 36

Results of the Regression Analysis Examining the Contributions of Fatigue, Months in Specialty, and Critical Care Experience on Critical Care Reaction Time 7 at Altitude with Noise

	CCRT7Alt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	.004	.004	.169	.889	.382
FAST	.417	.526	.152	.792	.436
CCEXP	-.410	.652	-.121	-.628	.535

Adjusted R^2 .040, p = .603

CCRT7Alt = Critical Care Reaction Time 7 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

A regression analysis of CCRT14 with altitude (CCRT14Alt) and noise as the three predictors entered simultaneously as one block accounted for 20.8% of the variance, and was statistically significant [F (3, 29) = 3.539, p = .028]. Experience [t (3, 29) = -3.03, p = .005] contributed significantly. Fatigue [t (3, 29) = -1.188 = .245], and Critical Care Experience [t (3, 29) = -.599, p = .554] did not contribute significantly to the variance in CCRT14 with altitude.

Table 37

Correlations of Critical Care Reaction Time 14 at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCRT14Alt	EXP	FAST	CCEXP
CCRT14Alt	1.0	-.496*	-.160	-.090
EXP	-.496*	1.0	-.046	.042
FAST	-.160	-.046	1.0	-.154
CCEXP	-.090	.042	-.154	1.0

*p = .003

CCRT14Alt = Critical Care Reaction Time 14 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 38

Results of the Regression Analysis Examining the Contributions of Fatigue, Months in Specialty, and Critical Care Experience to Critical Care Reaction Time 14 at Altitude with Noise

	CCRT14Alt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	-.009	.003	-.501	-2.03	.005
FAST	-.448	.377	-.199	-1.188	.244
CCEXP	.280	.467	-.100	-.599	.554

Adjusted R^2 .208, p = .028

CCRT14Alt = Critical Care Reaction Time 14 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

A regression analysis of CCRT15 with altitude (CCRT15Alt) and noise as the three predictors entered simultaneously as one block accounted for 3.1% of the variance, and was not statistically significant [F (3, 29) = .706, p = .557]. Experience [t (3, 29) =

.071, p = .944], Fatigue [t (3, 29) = .831 = .414], and Critical Care Experience [t (3, 29) = -1.053, p = .301] did not contribute significantly to the variance in CCRT15 with altitude.

Table 39

Correlations of Critical Care Reaction Time 15 at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCRT15Alt	EXP	FAST	CCEXP
CCRT15Alt	1.0	-.002	.189	-.225
EXP	-.002	1.0	-.046	.042
FAST	.189	-.046	1.0	-.154
CCEXP	-.225	.042	-.154	1.0

No significance

CCRT15Alt = Critical Care Reaction Time 15 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 40

Results of the Regression Analysis Examining the Contributions of Fatigue, Months in Specialty, and Critical Care Experience to Critical Care Reaction Time 15 at Altitude with Noise

	CCRT15Alt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	-.000	.003	.013	.071	.944
FAST	.278	.335	.159	.831	.414
CCEXP	-.437	.415	-.201	-1.053	.302

Adjusted R^2 .031, p = .557

CCRT15Alt = Critical Care Reaction Time 15 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

A regression analysis of CCRT16 with altitude (CCRT16Alt) and noise as the three predictors entered simultaneously as one block accounted for 6.3% of the variance, and was not statistically significant [F (3, 29) = .428, p = .735]. Experience [t (3, 29) = -.710, p = .484], Fatigue [t (3, 29) = -.174 = .863], and Critical Care Experience [t (3, 29) = -.858, p = .399] did not contribute significantly to the variance CCRT16 with altitude.

Table 41

Correlations of Critical Care Reaction Time 16 at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCRT16Alt	EXP	FAST	CCEXP
CCRT16Alt	1.0	-.142	-.002	-.167
EXP	-.142	1.0	-.046	.042
FAST	-.002	-.046	1.0	-.154
CCEXP	-.167	.042	-.154	1.0

No significance

CCRT16Alt = Critical Care Reaction Time 16 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 42

Results of the Regression Analysis Examining the Contributions of Fatigue, Months in Specialty, and Critical Care Experience to Critical Care Reaction Time 16 at Altitude with Noise

	CCRT16alt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	-.002	.003	-.136	-.710	.484
FAST	-.070	.404	-.034	-.174	.863
CCEXP	-.429	.500	-.166	-.858	.399
Adjusted R^2 .063, p = .735					

CCRT16Alt = Critical Care Reaction Time 16 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Interaction of Fatigue, Critical Care Experience, and Experience on CCS, CCP, and CCE

The interaction between Fatigue, Experience, and Critical Care Experience was evaluated to examine the potential effects. Addition of the interaction term did not add to the prediction of CCS [F (4, 29) = .166, p = .954], CCP [F (4, 29) = .178, p = .948] or CCE [F (4, 29) = .847, p = .509] at altitude with noise.

Interaction of Experience, Fatigue and Critical Care Experience on CCRTs

The interaction between Experience, Fatigue, and Critical Care Experience was evaluated to examine the potential effects. Addition of the interaction term EXP*FAST*CCEXP to the regressions for each CCRT made the prediction statistically significant for only Critical Care Time 14. A regression analysis of CCRT14 with altitude (CCRT14Alt) and noise as the three predictors with the addition of the interaction term

EXP*FAST*CCEXP entered simultaneously as one block accounted for 32.1% of the variance in CCRT14, and was statistically significant [F (4, 29) = 4.420, p = .008]. Experience [t (4, 29) = -2.934, p = .007], Fatigue [t (4, 29) = -2.519, p = .019], Critical Care Experience [t (4, 29) = -2.302, p = .030] and the interaction term EXP*FAST*CCEXP [t(4, 29) = 2.303, p = .030] all made a statistically significant contribution to the model predicting CCRT14.

Table 43

Correlations of Critical Care Reaction Time 14 at Altitude with Noise, Months in Specialty, Fatigue Assessment Score Transformed, Critical Care Experience, and the interaction of Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	CCRT14Alt	EXP	FAST	CCEXP	EXP*FAST*CCEXP
CCRT14Alt	1.0	-.496**	-.160	-.090	-.444**
EXP	-.496**	1.0	-.046	.042	.918*
FAST	-.160	-.046	1.0	-.154	.096
CCEXP	-.090	.042	-.154	1.0	.329***
EXP*FAST*CCEXP	-.444**	.918*	.096	.329***	1.0

* p < .001, **p < .01, ***p < .05

CCRT14Alt = Critical Care Reaction Time 14 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience, EXP*FAST*CCEXP = Interaction Term for Experience (Months in Specialty), Fatigue Assessment Score Transformed, and Critical Care Experience

Table 44

Results of the Regression Analysis Examining the Contributions of Fatigue, Months in Specialty, and Critical Care Experience, and their interaction on Critical Care Reaction Time 14 at Altitude (CCRT14Alt) with Noise

	CCRT14Alt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	-.039	.013	-2.161	-2.934	.007
FAST	-1.217	.483	-.541	-2.519	.019
CCEXP	-1.903	.827	-.682	-2.302	.030
EXP*FAST*CCEXP	.004	.002	1.817	2.303	.030
Adjusted R^2	.321, p = .008				

CCRT14Alt = Critical Care Reaction Time 14 with altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience, EXP*FAST*CCEXP = Interaction Term for Experience (Months in Specialty), Fatigue Assessment Score Transformed, and Critical Care Experience

Summary of Regressions with the Cognitive Variables

The regressions indicated that Fatigue, Experience, and Current Critical Care Experience individually did not significantly contribute cognitive performance in this study with the exception of Critical Care Time 14, Defibrillates 1st time. The regression for CRRT 14 with altitude and noise as was statistically significant, and accounted for 20.8% of the variance in CCRT14. Experience was the only statistically significant predictor in the model for CCRT 14.

Addition of the interaction of the three predictors Experience, Fatigue, and Current Critical Care Experience made a statistically significant contribution to Critical Care Reaction Time 14 (Defibrillates 1st time). The model with the three predictors and their interaction term explained 32.1% of the variance in CCRT14. The interaction showed that participants with more experience, current critical care experience, and high fatigue scores took longer to defibrillate the first time than those with more experience, current critical care experience and low fatigue scores. The interaction showed that participants with less experience, current critical care experience, and low fatigue scores took longer to defibrillate the first time than those with more experience, current critical care experience and low fatigue scores. The interaction showed that participants with more experience, current critical care experience, and high fatigue scores defibrillated the first time in a similar amount of time as those with less experience, current critical care experience and high fatigue scores.

The regressions indicated that Experience, Fatigue, and Current Critical Care Experience individually significantly contributed to cognitive performance in this study as measured by CCRT 14 only. Hypothesis 2A is supported by the regression results of CCRT 14. Hypothesis 2A is not supported by the results of the regressions for CCS, CCP, CCE, ANAM TP Scores, and all of the CCRTs except CCRT 14. The interaction of the three predictors did make a statistically significant contribution to Critical Care Reaction Time 14 (Defibrillates 1st time). Hypothesis 2A is supported by these results with the addition of the interaction term.

Hypothesis 2B

To examine the relationship between physiologic performance and Experience (Months in Specialty), Fatigue Assessment Score Transformed, and Current Critical Care Experience with noise and altitude, the physiologic variables were averaged and examined for the assumptions of multiple regression. Average HR, average SBP, average DBP, and average RR at altitude were all normally distributed. The Reflected Square Root Transformation of average Oxygen Saturation resulted in a normal distribution.

The Average HR at altitude was regressed on the three predictor variables (see Table 45 and 46) with noise and altitude. The Average SBP at altitude was regressed on the three predictor variables (see Table 47 and 48) with noise. The Average DBP at altitude was regressed on the three predictor variables (see Table 49 and 50) with noise. The Average RR at altitude was regressed on the three predictor variables (see Table 51 and 52) with noise. The Reflected Square Root Transformation of average Oxygen Saturation at altitude was regressed on the three predictor variables (see Table 53 and 54) with noise.

Average Heart Rate

A regression analysis of Average HR with altitude (AHRAlt) and noise with the three predictors accounted for 9% of the variance, and was not statistically significant [F (3, 29) = .199, p = .896]. Experience [t (3, 29) = -.537, p = .596], Fatigue [t (3, 29) = .318 = .753], and Critical Care Experience [t (3, 29) = -.364, p = .719] did not contribute significantly to the variance.

Table 45

Correlations of Average HR at Altitude (AHRAlt), Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	AHRAlt	EXP	FAST	CCEXP
AHRAlt	1.0	-.110	.078	-.085
EXP	-.110	1.0	-.046	.042
FAST	.078	-.046	1.0	-.154
CCEXP	-.085	.042	-.154	1.0

No significance

AHRAlt = Average Heart Rate at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 46

Results of the Regression Analysis Examining the Contributions of Months in Specialty (EXP), Fatigue (FAST) and Critical Care Experience (CCEXP) to Average HR at Altitude (AHRAlt) with Noise

	AHRAlt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	.018	.033	-.104	-.537	.596
FAST	1.303	4.098	.062	.318	.753
CCEXP	-1.847	5.075	-.071	-.364	.719

Adjusted R^2 .090, p = .896

AHRAlt = Average Heart Rate at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

<u>*Average Systolic Blood Pressure*</u>

A regression analysis of Average SBP with altitude (ASBPAlt) and noise as the three predictors entered simultaneously as one block accounted for 2.6% of the variance, and was not significant [F (3 , 29) = .751, p = .532]. Experience [t (3, 29) = -.895, p =

.382], Fatigue [t (3, 29) = 2.342 = .030], and Critical Care Experience [t (3, 29) = 1.329, p = .199] did not contribute significantly to the variance of Average SBP.

Table 47

Correlations of Average SBP at Altitude (AltSBP), Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	ASBPAlt	EXP	FAST	CCEXP
ASBPAlt	1.0	-.109	.240	.069
EXP	-.109	1.0	-.046	.042
FAST	.2409	-.046	1.0	-.154
CCEXP	.069	.042	-.154	1.0

No significance

ASBPAlt = Average Systolic Blood Pressure at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 48

Results of the Regression Analysis Examining the Contributions of Months in Specialty (EXP), Fatigue (FAST) and Critical Care Experience (CCEXP) to Average SBP at Altitude (ASBPAlt) with Noise

	AltSBP				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	-.025	.047	-.102	-.542	.593
FAST	7.825	5.896	.253	1.327	.196
CCEXP	4.315	7.302	.113	.591	.560

Adjusted R^2 .026, p = .532

ASBPAlt = Average Systolic Blood Pressure at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Average Diastolic Blood Pressure

A regression analysis of Average DBP with altitude (ADBPAlt) and noise as the three predictors entered simultaneously as one block accounted for 10.1% of the variance, and was not statistically significant [F (3, 29) = .113, p = .951]. Experience [t (3, 29) = -.304, p = .763], Fatigue [t (3, 29) = .217, p = .830), and Critical Care Experience [t (3, 29) = .482, p = .634] did not contribute significantly to the variance of average DBP.

Table 49

Correlations of Average DBP at Altitude (ADBPAlt), Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	ADBPAlt	EXP	FAST	CCEXP
ADBPAlt	1.0	-.057	.031	.086
EXP	-.057	1.0	-.046	.042
FAST	.031	-.046	1.0	-.154
CCEXP	.086	.042	-.154	1.0

No significance

ADBPAlt = Average Diastolic Blood Pressure at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 50

Results of the Regression Analysis Examining the Contributions of Months in Specialty (EXP), Fatigue (FAST) and Critical Care Experience (CCEXP) to Average DBP at Altitude (AltSBP) with Noise

	ADBPAlt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	-.012	.039	-.059	-.304	.763
FAST	1.071	4.934	.043	.217	.830
CCEXP	2.948	6.111	.095	.482	.634

Adjusted R^2 .101, p = .951

ADBPAlt = Average Diastolic Blood Pressure at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

<u>*Average Respiratory Rate*</u>

A regression analysis of Average RR with altitude (ARRAlt) and noise as the three predictors entered simultaneously as one block accounted for 19.7% of the variance, and was not statistically significant [F (3, 29) = .144, p = .933]. Experience [t (3, 29) = .138, p = .891], Fatigue [t (3, 29) = -.328, p = .746], and Critical Care Experience [t (3, 29) = .486, p = .631] did not contribute significantly to the variance of Average RR.

Table 51

Correlations of Average RR at Altitude (ARRAlt), Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	ARRAlt	EXP	FAST	CCEXP
ARRAlt	1.0	.034	-.081	.107
EXP	.034	1.0	-.046	.042
FAST	-.081	-.046	1.0	-.154
CCEXP	.107	.042	-.154	1.0

No significance

ARRAlt = Average Respiratory Rate at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 52

Results of the Regression Analysis Examining the Contributions of Months in Specialty (EXP), Fatigue (FAST) and Critical Care Experience (CCEXP) to Average RR at Altitude (ARRAlt) with Noise

	ARRAlt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	.001	.006	.027	.138	.891
FAST	-.244	.744	-.065	-.328	.746
CCEXP	.448	.922	.096	.486	.631

Adjusted R^2 .097, p = .933

ARRAlt = Average Respiratory Rate at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Average Oxygen Saturation Transformed

A regression analysis of the Reflected Square Root Transformation of average Oxygen Saturation (ASATTAlt) at altitude with noise as the three predictors entered simultaneously as one block accounted for 3.5% of the variance, and was not significant [F (3, 29) = .675, p = .575]. Experience [t (3, 29) = -.196, p = .846], Fatigue [t (3, 29) =

1.161 = .256], and Critical Care Experience [t (3, 29) = .964, p = .344] did not contribute significantly to the variance of average Oxygen Saturation Transformed.

Table 53

Correlations of Average Oxygen Saturation Transformed at Altitude (ASATTAlt), Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	ASATTAlt	EXP	FAST	CCEXP
ASATTAlt	1.0	-.040	.195	.149
EXP	-.040	1.0	-.046	.042
FAST	.195	-.046	1.0	-.154
CCEXP	.149	.042	-.154	1.0

No significance

ASATTAlt = Oxygen Saturation Transformed at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 54

Results of the Regression Analysis Examining the Contributions of Months in Specialty (EXP), Fatigue (FAST) and Critical Care Experience (CCEXP) to Average SATT at altitude (ASATTAlt) with Noise

	ASATTAlt				
Variable	Altitude (n = 24)				
	B	SE	β	t	Sig.
EXP	.000	.002	-.037	-.196	.846
FAST	.224	.193	.222	1.161	.256
CCEXP	.230	.239	.184	.964	.344

Adjusted R^2 .035, p = .575

ASATTAlt = Oxygen Saturation Transformed at altitude, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Interaction of Fatigue, Critical Care Experience, and Experience on the Physiological Variables

The interaction between Experience, Fatigue, and Critical Care Experience was evaluated to examine the potential effects on each of the regression models for the physiological variables. Addition of the interaction terms did not add to the prediction of any of the physiological variables. Addition of the interaction term did not add to the prediction of AHR [F (4, 29) = .372, p = .826], ASBP [F (4, 29) = .587, p = .675], ADBP [F (4, 29) = .157, p = .958], ARR [F (4, 29) = .432, p = .784] or ASATT [F (4, 29) = .499, p = .736] at altitude with noise.

Summary of Regressions with the Physiological Variables

The regressions indicated that Fatigue, Experience, and Current Critical Care Experience did not significantly contribute to physiological performance in this study. Hypothesis 2B was not supported.

Summary of Results for Research Question 2

The regressions indicated that Experience, Fatigue, and Current Critical Care Experience with altitude and noise did not significantly contribute to cognitive or physiological performance in this study with the exception of Critical Care Time 14, Defibrillates 1st time. In the regression for CCRT 14 with altitude and noise, Experience, Fatigue, and Current Critical Care Experience all made a statistically significant contribution. A summary of the regression results for the cognitive variables can be found in Tables 55 and 56. The regressions with the addition of the interaction term significantly contributed to Critical Care Reaction Time 14, Defibrillates 1st time. A summary of the regression results for the physiological variables can be found in Tables 57 and 58.

Table 55

Summary of Results and Adjusted R^2 from Regressions of the Cognitive Variables Critical Care Score, Critical Care Percent, Critical Care Errors and Omissions and Critical Care Reaction Times to Altitude with Noise with the predictors Months in Specialty, Fatigue Assessment Score, and Critical Care Experience

	CCS	CCP	CCE	CCRT4	CCRT5	CCRT6	CCRT7	CCRT14	CCRT15	CCRT16
Model Significance	p = .897	p = .886	p = .666	p = .710	p = .619	p = .120	p = .603	**p = .028**	p = .557	p = .735
Adjusted R^2	.090	.088	.051	.059	.043	.105	.04	.208	.031	.063

CCS = Critical Care Score, CCP = Critical Care Score Percent, CCE = Critical Care Errors and Omissions, CCRT = Critical Care Reaction Times

Table 56

Summary of the Independent Contributions of the predictors Months in Specialty, Fatigue Assessment Score, and Critical Care Experience to the Models Explaining Each of the Cognitive Variables, Critical Care Score, Critical Care Percent, Critical Care Errors and Omissions and Critical Care Reaction Times, to Altitude with Noise

	CCS	CCP	CCE	CCRT4	CCRT5	CCRT6	CCRT7	CCRT14	CCRT15	CCRT16
EXP	p = .749	p = .790	p = .638	p = .481	p = .332	p = .060	p = .382	**p = .005**	p = .944	p = .484
FAST	p = .538	p = .480	p = .386	p = .395	p = .690	p = .170	p = .436	p = .245	p = .414	p = .863
CCEXP	p = .679	p = .719	p = .380	p = .661	p = .430	p = .793	p = .535	p = .554	p = .302	p = .399

CCS = Critical Care Score, CCP = Critical Care Score Percent, CCE = Critical Care Errors and Omissions, CCRT = Critical Care Reaction Times, EXP = Months in Specialty, FAST = Fatigue Assessment Score Transformed, CCEXP = Critical Care Experience

Table 57

Summary of Results and Adjusted R^2 from Regressions of the Physiological Variables Average Heart Rate, Average Systolic Blood Pressure, Average Diastolic Blood Pressure, Average Respiratory Rate, and Transformed Average Oxygen Saturation to Altitude with Noise with the predictors Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience

	AHR	ASBP	ADBP	ARR	ASATT
Model Significance	p = .896	p = .532	p = .951	p = .933	p = .575
Adjusted R^2	.090	.026	.101	.097	.035

AHR = Average Heart Rate, ASBP = Average Systolic Blood Pressure, ADBP = Average Diastolic Blood Pressure, ARR = Average Respiratory Rate, and SATT = Transformed Average Oxygen Saturation

Table 58

Summary of the Independent Contributions of the predictors Months in Specialty, Fatigue Assessment Score Transformed, and Critical Care Experience to the Models Explaining Each of the Physiological Variables: Average Heart Rate, Average Systolic Blood Pressure, Average Diastolic Blood Pressure, Average Respiratory Rate, and Transformed Average Oxygen Saturation to Altitude with Noise

	AHR	ASBP	ADBP	ARR	ASATT
EXP	p = .596	p = .593	p = .402	p = .891	p = .846
FAS	p = .753	p = .196	p = .178	p = .746	p = .256
CCE	p = .719	p = .560	p = .360	p = .631	p = .344

AHR = Average Heart Rate, ASBP = Average Systolic Blood Pressure, ADBP = Average Diastolic Blood Pressure, ARR = Average Respiratory Rate, and SATT = Transformed Average Oxygen Saturation

Summary of All Results

Noise and altitude were shown to have a statistically significant negative effect on Critical Care Scores and Critical Care Percent. Noise and altitude had a statistically significant effect on Critical Care Errors and Omissions. Altitude also had a significant effect on Critical Care Reaction Time 6 (Starts bag-valve-mask breathing). At the higher altitude, Critical Care Scores and Critical Care Percent were lower than at ground altitude. At the higher altitude, Critical Care Errors and Omissions were higher than at ground altitude. Critical Care Reaction Time 6 was higher with the high altitude condition than the low altitude condition. There was an interaction effect of noise and altitude on CCRT 5 (Hangs IV fluids). Together, noise and altitude decreased CCRT5. Altitude was shown to impact Heart Rate, Respiratory Rate, and Oxygen Saturation. At higher altitude, Heart Rate and Respiratory Rate were higher than at ground altitude. At higher altitude, Oxygen Saturation was lower than at ground altitude.

Regression analyses of performance which included the predictors Experience, Fatigue, and Current Critical Care Experience, found significant results for only Critical Care Reaction Time 14. In this regression, Experience was the statistically significant predictor. With the addition of the interaction of Current Critical Care Experience, Experience, and Fatigue Assessment Score to the regression of Critical Care Reaction Time 14 at altitude with noise, statistical significance was revealed. All three predictors and their interaction term significantly contributed to the model for CCRT 14.

CHAPTER V: SUMMARY AND DISCUSSION, LIMTATIONS, IMPLICATIONS AND RECOMMENDATIONS

SUMMARY AND DISCUSSION

The first purpose of this study was to determine the impact of altitude-induced hypoxia and aircraft noise on cognitive and physiological performance during critical care delivery. Cognitive performance was defined as performance of critical care skills during an ACLS-based scenario as measured by an intervention checklist. From the checklist, Critical Care Score, Critical Care Percent, and number of Critical Care Errors and Omissions were determined during a video-recorded review of the performance sessions. The researcher was blinded to the hypoxia condition of each session. Cognitive performance was also measured through critical care reaction times observed for several of the interventions observed during the scenarios. The ANAM4 computer-based neurocognitive test battery was also used to measure cognitive performance. Physiological performance was measured four times during each scenario via heart rate, systolic blood pressure, diastolic blood pressure, respiratory rate, and oxygen saturation.

The second purpose of this study was to examine the contributions of fatigue and clinical experience to cognitive and physiological performance during critical care delivery with aircraft cabin noise and altitude. Fatigue was measured using the Fatigue Assessment Scale (DeVries, Michielsen, & VanHeck, 2003; Michielsen, DeVries, & VanHeck, 2003). Clinical experience was measured in the number of months in specialty, and whether or not the participants had current critical care experience.

The theoretical framework for this study was based on Astrand's framework on work physiology (Astrand, Rodahl, Dahl, & Stromme, 2003). The main focus of the framework is to guide the assessment of the effects of the working environment on the worker. The framework proposes that intrinsic factors and extrinsic factors affect performance. Intrinsic factors are characteristics within the individual, and extrinsic factors are characteristics that occur outside the individual in the environment. Using this theoretical framework, a 2 x 2 x 4 repeated measures study was designed to investigate the effects of aircraft cabin altitude and noise on critical care performance. Altitude and noise are extrinsic factors affecting performance. Experience and fatigue were also studied to see their impact on critical care performance. Experience and fatigue are intrinsic factors affecting performance.

Data were analyzed using RM ANOVA and multiple regression statistical techniques. The repeated measures design allowed the participants to act as their own controls. The randomized block assignment incorporated counterbalancing of the altitude order to prevent order effects, and served to create equal groups based on noise assignment. Assignment of the same number of participants to each combination of categories of the explanatory variables allowed assessment of the unique effect of each explanatory variable and its interactions on the dependent variables (Iversen & Norpoth, 1987).

Military registered nurses with critical care experience from the Baltimore-Washington area were recruited to participate in the study. They were asked to perform care during two simulated patient care scenarios, under simulated conditions of military aircraft cabin noise and altitude. The participants all experienced both ground oxygen (21%) levels and cabin altitude oxygen (15%) levels by wearing a mask that delivered the appropriate concentration, during the two scenarios in a counterbalanced order. The participants were blinded to the oxygen levels. Half the participants experienced the aircraft cabin noise, 86 db(A), and the half performed under ambient noise levels, averaging 54 dB(A). During the noise sessions participants wore earplugs for hearing protection, which provided a noise attenuation of 29 dB (Aearo Company, 2007). Each session began with a 30-minute acclimatization period prior to performance testing. In addition to observing interventions performed during each simulated patient care scenario, physiological parameters were measured four times during each scenario. The participants completed an ANAM4 neurocognitive test battery immediately after each of the two scenarios.

Characteristics of the Participants

All of the 60 participants in the study were military registered nurses. Physicians were recruited but did not volunteer to participate. Forty-one (68.4%) participants gave critical care nursing as their current primary specialty. All had experience with ACLS. Months of experience ranged from 3 to 255, with the average being 93 months (7.75 years). The majority of the participants were in the Air Force (66.7%), 13 (21.7%) were in the Army, and 7 (11.7 %) were in the Navy. Mean time in military service was 14.05 years. Thirty-two (53.3%) participants were company grade or junior officers, and 28 (46.67%) were field grade or senior officers. Thirty-two of the participants had been deployed (53.3%), and during deployment, 18 (30%) had transported patients. Average age of the participants was 39.23 years. Forty-two percent of the participants were male. Forty-three (71.7%) of the participants were white, and 13 (21.7%) were black. Mean height and weight were 67.27 inches and 166.40 pounds. The majority of the participants had never smoked (78.3%), and only three (5.0%) currently smoked at the time of the study. Randomized assignment resulted in equal groups based on the two noise conditions.

Research Question 1

The first research question investigated the impact of military aircraft noise and altitude-induced hypoxia on cognitive and physiological performance during a simulated critical care patient scenario. The following hypotheses were tested:

Hypothesis 1A: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise.

Hypothesis 1B: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise.

Hypothesis 1C: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with altitude-induced hypoxia.

Hypothesis 1D: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with altitude-induced hypoxia.

Hypothesis 1E: Cognitive performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise and altitude-induced hypoxia.

Hypothesis 1F: Physiological performance of CCATT personnel during a simulated critical care patient scenario differs with military aircraft noise and altitude-induced hypoxia.

The independent variables were noise and altitude, each with two levels. The dependent variable of cognitive performance was measured through Critical Care Score, Critical Care Percent, Critical Care Errors and Omissions, Critical Care Reaction Times, and ANAM4 Throughput scores. The seven Critical Care Reaction Times measured in this study were:

CCRT4: Puts on oxygen

CCRT5: Hangs IV fluids

CCRT6: Starts BVM (bag-valve-mask) breathing

CCRT7: Intubates/Advanced Airway

CCRT14: Defibrillates 1st time

CCRT15: Gives epinephrine 1 mg or Vasopressin 40 U IV

CCRT16: Gives Amiodarone 300 mg IV or Lidocaine, 1.5 mg/kg IV

The six ANAM4 tests selected for administration to the participants in this study were the Simple Reaction Time, 2-Choice Reaction Time, Code Substitution (Learning), Code Substitution (Delayed Memory), Mathematical Processing, and Logical Relations. The physiologic performance dependent variable was measured with heart rate, systolic blood pressure, diastolic blood pressure, respiratory rate, and oxygen saturation.

Cognitive Performance

Interaction of Noise and Altitude

The interaction effects of noise and altitude on cognitive performance were examined first. Hypothesis 1E, which proposed a difference in cognitive performance related to altitude and noise, was only supported by the results of CCRT5 and 6. The interaction effect measures the effect of noise and altitude, over and beyond their two separate effects (Iversen & Norpoth, 1987). In this study, noise and altitude acted together to decrease reaction time and improve performance than what was seen for their separate effects for CCRT5 (Hangs IV fluids). The interaction results approached significance for CCRT6 (Starts bag-valve-mask breathing). At altitude and noise, CCRT5 was lower than at altitude with no noise. At altitude it took longer for participants to hang IV fluids if there was no aircraft noise than if there was noise. At ground with noise, CCRT5 was higher than at ground with no noise. At ground, it took longer for participants to hang IV fluids if there was noise than if there was no noise. At altitude with noise, CCRT6 was lower than at altitude with no noise. At altitude it took participants longer to start BVM breathing if there was no noise than if there was noise. At ground with noise, CCRT6 was similar to at ground with no noise. At ground, noise condition did not affect how long it took participants to start BVM breathing.

Instead of seeing a negative effect and increasing reaction time due to altitude and noise, the opposite results occurred for Critical Care Reaction Time 5 and 6. This interaction in which performance was improved is difficult to explain. Perhaps the noise led to an increase in alertness and attention in the participants that was greater than the detrimental effects of hypoxia. The interaction effects for the remaining outcomes were not significantly different than the separate noise and altitude effects. This may be because the noise effects were positive and the altitude effects were negative and this led to a net result of no observable difference in the ANAM4 scores and the Critical Care Reaction Times 4, 7, 14, 15, and 16. While the opposite could also be true, that altitude was a positive influence, and noise was a negative influence, this interpretation is not supported by the literature. Another possible explanation is that reaction times and tests like those in the ANAM4 battery are not measuring the cognitive functions that are impacted by noise and altitude together. Lowe and colleagues (2007) reviewed the uses of the ANAM under extreme environmental conditions, and high altitude yielded significant results, but noise and moderate altitude were not studied. These tests may not be sensitive enough to detect changes under the conditions of the present study. Yet another alternative explanation for the results of this study is that the exposure time to the testing conditions of altitude and noise was not long enough to lead to observable changes in cognitive performance. The longest time of exposure during the study was 120 minutes, with a 15 minute break in the middle. A time of exposure of 120 minutes does not begin to approximate the time that CCATT members are exposed during flights from Iraq to Germany, or Germany to the continental United States, which can be eight hours or more. A longer exposure may produce different results.

The differences seen in Critical Care Reaction Time 5, time it took to hang IV fluids, and Time 6, the time to start BVM breathing for the patient, while statistically significant, may be clinically insignificant. A difference in a second or two in the initiation of IV fluids as seen in this study is probably not important to a patient's outcome, and there is likely a great variation in the time it takes a clinician to set up the

IV fluids for administration as well. Finally, the absence of changes in some aspects of performance may be reflective of the body's ability to effectively compensate under some adverse conditions.

In the one study found in the literature where a combination of altitude of 8,000 feet and noise of 85 dB(A) was examined, conditions very similar to the present study, intellectual judgment was not significantly effected by noise and altitude (Pierson, 1973). Pierson's (1973) study is consistent with the results of the present study where there was no interaction effect seen between noise and altitude for the many of the neuropsychological outcome measures.

In Astrand's model (2003) on work performance, altitude and noise are extrinsic factors that influence the service functions of the body, the energy yielding processes, and therefore work performance. In the present study, the model has been adapted to differentiate between cognitive and physiological performance. The model depicts straight forward linear relationships between the extrinsic and intrinsic factors and the body's service functions. The results of the interaction of noise and altitude on CCRT 5 and 6 demonstrate that these relationships are likely more complicated than portrayed in the model. The model does not designate whether the factors that influence performance have a positive or negative effect. These results support a more complex model, and provide more information to expand the model proposed by Astrand and colleagues (2003).

In Astrand's model, the nature of work to be performed also has an influence over work performance. Mental load (light or heavy), duration (brief or prolonged), and schedule (day or night) are factors that could have influenced performance in this study.

While deployed, CCATT members are likely to have to perform work of heavy cognitive load during round-the-clock shifts over a long time with more than one patient in their care. CCATTs can have up to four to six patients in their charge during a mission. This increases the cognitive demand in a way not portrayed in the present study. In this study performance was measured during the daytime, with one patient, and the entire study lasted a maximum of 3.5 hours.

Intrinsic factors that influence performance are motivation and stress, which can also both have positive or negative effects. Several participants in the study expressed that they were nervous just prior to the first scenario, because their performance was being judged. On the other hand, a couple of participants commented on the fact that the scenario was a simulation and their performance would not impact a real patient's outcome. It is difficult to translate these intrinsic factors in comparison to stress and motivation in deployed CCATT members caring for many critically ill patients during flight.

Noise

Of the cognitive measures, Critical Care Scores, Percent, and Errors and Omissions were found to be significantly influenced by noise. Critical Care Scores were lower at the high noise than at the low noise conditions. Critical Care Score Percent was lower at the high noise than at the low noise conditions. Critical Care Errors and Omissions were higher at the high noise than at the low noise conditions. The results show that noise had an influence on cognitive performance as measured by scores and errors and omissions during the scenario, and supports Hypothesis 1A. The difference seen in Score, Percent, and Errors and Omissions may be because noise impacts performance of work of high cognitive demand, and delivery of critical care is a very cognitively demanding job.

Another possibility is that noise interfered with the ability of the nurses to adequately assess the patient. Many participants in the study had difficulty listening to breath sounds in the noise condition. In the scenario when the simulated patient deteriorated and his oxygen saturation decreased severely, many participants incorrectly decided placement of a chest tube was an appropriate intervention. The simulated patient also complained of nausea, chest pain, and difficulty breathing, but the majority of the participants in the noise condition could not hear these audible cues. Hypothesis 1A was supported for Critical Care Score, Critical Care Percent and Critical Care Errors and Omissions. Hypothesis 1A was not supported for the Critical Care Reaction Times or ANAM Throughput measures. Perhaps noise had no effect on the neurocognitive measures because these cognitive tests were less demanding than critical care delivery. The limited time of exposure may also be a factor.

The results in this study, a significant effect of noise on Critical Care Score, Critical Care Percent, and Critical Care Errors and Omissions, are consistent with the study by Pierson (1971), in which noise levels of 99 dB(A) over four hours showed a statistically significant increase in number of errors. Neurocognitive tests completed by residents during exposure to operating room noise at a level of 77.32 dB(A) showed statistically significant decreases in cognitive performance with the noise (Murthy, Malhotra, Bala, & Raghunathan, 1995). The findings in the present study on the ANAM4 tests are not consistent with the results of the Murthy et al. study, but the Critical Care Scores, Percent, and Errors and Omissions results corroborate the Murthy study results.

There may be many variables not measured or reported that would have influenced the results in the Murthy study. Residents are known to work up to 80 hours per week or more, and their performance may have been influenced by fatigue. The participants in the present study generally reported low levels of fatigue.

In a study in an industrial setting, noise tended to increase error rates associated with tasks of high cognitive loads or with a high degree of control precision, to reduce errors with physical strength, and to have no effect on errors associated with manual dexterity (Levy-Leboyer, 1989). The effect on errors under the cognitive load with noise in the present study is consistent with the findings of Levy-Leboyer (1989).

The differences seen in score are equivalent to one less intervention being performed for the patient. Every intervention on the scenario checklist is critical, so this difference may be clinically as well as statistically significant. Inappropriate or missed interventions could negatively impact patient outcomes.

Altitude

Critical Care Score and Percent were significantly affected by altitude, as was Errors and Omissions. Critical Care Scores were lower at the high altitude than at the low altitude conditions. Critical Care Score Percent was lower at the high altitude than at the low altitude conditions. Critical Care Errors and Omissions were higher at the high altitude than at the low altitude conditions.

No statistically significant differences were found due to altitude on the other Critical Care Reaction Times, or the ANAM4 neurocognitive battery tests. This may be because the cognitive processes reflected in the ANAM4 are different, leading to differing results. Rapid Critical Care Reaction Times may not be the important measure of performance in caring for patients. The speed of the reactions may be less important that the quality of the reactions. In other words, if the clinician performed the right intervention, the variation in time it took may not be as important. Or this may be true up to certain time parameters. Higher cognitive function may be required to synthesize all the information required to provide appropriate care of a critically ill patient as he deteriorates and has a cardiopulmonary arrest, than to react quickly or do the Neurocognitive tests. This higher cognitive function may be more influenced by oxygen levels of 15%, equivalent to an altitude of 8,000 feet.

Another possibility is that the other measures would be affected by a longer exposure to altitude. The hypoxia condition in this study was of a shorter duration in comparison to intra-theater CCATT missions, which can last in excess of eight hours. In a study of passenger discomfort related to aircraft cabin altitude, there was a statistically significant increase in complaints of discomfort after 3 to 9 hours of simulated flight at 8,000 feet (Muhm et al., 2007). One study that included tests similar to real life situations over long testing periods of several hours yielded statistically significant results for both cognitive and physiological measures. Nesthus, Rush, and Wreggitt (1997) found increases in errors at an altitude of 10,000 feet on day three and four of a four-day testing schedule in a flight simulator. Other researchers examined the effects of prolonged exposure to hypoxia of altitude at 10,000 feet (Vaernes, Owe, & Myking, 1984). Reaction time significantly decreased during the session. Vaernes, Owe, and Myking (1984) tested neurocognitive function during 6.5 hours of exposure to 10,000 feet altitude. They found statistically significant differences in short-term memory and reaction time, but there was not a linear relationship with time of exposure. The findings in these last two studies are inconclusive that a longer testing session might have yielded different and significant results for the ANAM4 and other cognitive measures that were not statistically significant in the present study after 30 to 50 minutes of exposure to testing conditions in each session.

This study is a unique examination of the delivery of critical care in a military aircraft cabin environment. In past studies where cognitive performance with altitude was examined with neurocognitive tests, the results are mixed. Fiorca, Burr and Moses (1971) did not find a statistically significant difference in vigilance test scores at 11,500 feet altitude. Pavlicek et al. (2005) did not see statistically significant results on neuropsychological tests with altitudes up to 15,000 feet. At an altitude of 12,000 feet, Li et al. (2000) found statistically significant differences in a 4-choice reaction time test, but not simple reaction time or other tests. Kida and Imai (1993) saw statistically significant changes in reaction time at 13,500 feet. Wu and colleagues (1998) found a statistically significant difference in math scores after one hour of exposure to 12,000 feet altitude. Blogg and Gennser (2006) compared the effects of breathing 10%, 15%, and 21% oxygen, and only found statistically significant differences in psychomotor tests (reaction time, spatial orientation, voluntary repetitive movement, and fine manipulation) at 10% oxygen levels.

The lack of statistically significant findings of this study in the ANAM4 tests with 8,000 feet altitude is not unprecedented in the literature that includes neurocognitive tests. Select neurocognitive tests have shown statistical significance at slightly higher altitudes, but the results are not consistent.

In a study which examined the effects of altitude on memory, it was determined that performance during high memory load was significantly negatively affected (Bartholomew et al., 1999). High cognitive load was found to affect neurocognitive scores at an altitude of 8,000 feet in another study, where the more difficult tasks were seen to be significantly affected at altitudes of 8,000 feet (Kelman & Crow, 1969). These findings from the literature are consistent with the findings in this study on the critical care performance measures.

While significant results were obtained with a scenario based on ACLS, it is possible that another complex scenario would have had significant results in reaction times as well. Because the critical care nurses in this study have taken an ACLS course, some several times, they may have been performing based on repetitive training and ingrained memory. Another complex scenario that had not been used in training, but that required complex higher cognitive functioning to navigate might have yielded more statistically significant results.

Hypothesis 1C was supported for Critical Care Score, Critical Care Percent, Critical Care Errors and Omissions, and Critical Care Reaction Time 6. Hypothesis 1C was not supported for Critical Care Reaction Times 4, 5, 7, 14, 15, 16, or the ANAM TP measures. The significant results in the present study support the relationships depicted in the Astrand model, where altitude influences work. Astrand does not characterize the relationship as a positive or negative, but the present results support a negative effect of altitude on some measures of cognitive performance.

As discussed previously, cognitive load, duration of work, and time of day during which the work is being performed are also factors in the model that may have contributed to the results in the present study. The cognitive load of the critical care scenario appeared much higher than that of the ANAM4 tests. The short duration of the study and daytime testing may have influenced the results. Other factors, such as training, caffeine, and fitness may also have had an influence.

The significant results of this study demonstrate that noise and altitude affect certain aspects of critical care performance. The researcher observed during the study that some participants seemed to be more susceptible to those affects. Some participants displayed a more pronounced drop in oxygen saturation during the 15% oxygen condition. Under the noise condition, select participants could not hear anything during patient assessments, while others could assess breath sounds. In the future, it would be important to analyze which participants performed the best under these adverse conditions, and understand their characteristics that contributed to that superior performance.

Physiological Performance

Interaction of Noise and Altitude

The interaction effects of noise and altitude were analyzed first for each physiological outcome measure. The interaction of noise and altitude did not make a statistically significant difference in physiological performance as measured by heart rate, systolic blood pressure, diastolic blood pressure, respiratory rate, and oxygen saturation. Studies examining the interaction of noise and altitude and the impact on physiological response have not been reported in the literature. Hypothesis 1 F was not supported.

The model by Astrand and colleagues (2003) does not explicate an interaction effect, but does allow for one to exist. There may actually be an effect on physiological performance related to the interaction of noise and altitude, but the measures in the present study may not be the measures to examine to detect the effect. Compensation by the body may be occurring, and may be effective to prevent observable changes. Another possibility is that the effects would emerge under different conditions, for instance with higher fatigue levels or after longer exposure, or with the addition of another stressor of flight such as vibration.

Noise

Of the physiologic measures, respiratory rate was influenced by noise, resulting in a statistically significant difference. Average respiratory rate transformed was higher at the high noise than at the low noise conditions. Hypothesis 1 B was supported for RRT, but not for the other physiological measures. Noise has been shown to cause increased stress, and perhaps this explains why the respiratory rate was increased with noise.

The effect of music on modulating stress has been studied and certain types of music have been shown to change respiratory rate through an arousal effect (Bernardi, Porta, & Sleight, 2006). Perhaps aircraft noise also has an arousal effect. Gomez and Danuser (2004) studied arousal and respiratory response to a variety of music and noise stimuli, and reported an increase in arousal and respiratory rate to noise such as aircraft sound. A study examining the changes in the respiratory system when subjects were speaking under noise conditions showed a change in respiratory function (Huber, Chandrasekaran, & Wolstencroft, 2005). The subjects in the present study had to speak loudly in order to communicate during the noise sessions, and this too may have affected respiratory rate.

The literature on noise has reported that noise had impacted other physiological measures of stress, such as cortisol levels, heart rate, and sleep architecture (Gitanjali & Anath, 2003; Morrison, Haas, Shaffnew, Garrett, & Fackler, 2003). The results of the present study did not indicate physiological changes other than respiratory rate.

Altitude

Heart rate, respiratory rate, and oxygen saturation were the physiological measures significantly impacted by altitude. Heart rate was higher at high altitude than at low altitude. Transformed respiratory rate was higher at high altitude than at low altitude. Oxygen saturation was lower at high altitude than at low altitude. Hypothesis 1D was supported for heart rate, respiratory rate, and oxygen saturation, but not for systolic blood pressure or diastolic blood pressure.

In past studies where physiological performance with altitude was examined, the results are not consistent. Physiological differences were not found in a study by Fiorca and colleagues (1971) at 11,500 feet altitude over four hours, except for a statistically significant decrease in oxygen saturation. Kida and Imai (1993) also did not observe physiological differences at moderate altitude. In a study by Pavlicek and colleagues (2005), blood pressure and oxygen saturation was significantly different at 15,000 feet. In one study the researchers found statistically significant differences at 8,000 feet and higher altitudes in physiologic outcomes of heart rate, oxygen saturation, partial pressure of oxygen, and partial pressure of carbon dioxide (Nesthus, Rush, & Wreggit, 1997). In the present study, heart rate, and respiratory rate, as well as oxygen saturation were significantly different at an altitude of 8,000 feet. These results are consistent with some of the results in the literature (Fiorica, Burr, & Moses, 1971; Nesthus, Rush, & Wreggit, 1997; Pavlicek et al., 2005).

Physiological changes are to be expected with exposure to altitude. The impact of these changes on the individual as they care for patients is difficult to determine. Performing with less oxygen, a higher respiratory rate, and a higher heart rate may lead to fatigue at an earlier time. This may be the important relationship in examining the effects of altitude on physiological performance. Some participants in the study displayed lower oxygen saturations during the exposure to hypoxia than others. Certain individuals may have characteristics that make them more susceptible to the effects of lower oxygen levels.

Research Question 2

The second research question investigated whether fatigue and experience are related to cognitive and physiological performance with aircraft cabin noise and altitude. The following hypotheses were tested:

Hypothesis 2A: Fatigue and clinical experience predict cognitive performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia.

Hypothesis 2B: Fatigue and clinical experience predict physiological performance during a simulated critical care patient scenario with military aircraft noise and altitude-induced hypoxia.

The independent variables included aircraft cabin noise levels and aircraft cabin oxygen levels. The predictors were Fatigue, Experience, and Current Critical Care Experience. Fatigue was measured with the Fatigue Assessment Scale (Michielsen, DeVries, & VanHeck, 2003), and in the noise group the mean was 16.50 and the standard deviation was 4.16. In the noise group the mean length of experience was 97.6 months, and 79.9% of the participants had current critical care experience. The cognitive dependent variable measures included Critical Care Score, Critical Care Percent, Critical Care Errors and Omissions, and Critical Care Reaction Times. The physiologic dependent variable measures included heart rate, systolic blood pressure, diastolic blood pressure, respiratory rate, and oxygen saturation.

The regressions indicated that Fatigue, Experience, and Current Critical Care Experience individually did not significantly contribute cognitive performance in this study with the exception of Critical Care Time 14, Defibrillates 1st time. The regression for CRRT 14 with altitude and noise as was statistically significant, and accounted for 20.8% of the variance in CCRT14. Experience was the only statistically significant predictor in the model for CCRT 14. With the addition of the interaction of Current Critical Care Experience, Experience, and Fatigue Assessment Score to the regression of Critical Care Reaction Times 14 at altitude with noise, statistical significance was revealed. A regression analysis of CCRT14 with altitude and noise as the three predictors with the addition of the interaction term EXP*FAST*CCEXP accounted for 32% of the variance in CCRT14, and was statistically significant. Experience, fatigue, critical care experience, and the interaction term EXP*FAST*CCEXP all made a statistically significant contribution to the model predicting CCRT14.

The interaction showed that participants with more experience, current critical care experience, and high fatigue scores took longer to defibrillate the first time than those with more experience, current critical care experience and low fatigue scores.

Fatigue has been shown to negatively impact performance ((Gaba & Howard, 2002; Veasy, Rosen, Barzansky, Rosen, & Owens, 2002; Weinger & Ancoli-Israel, 2002). The interaction showed that participants with less experience, current critical care experience, and low fatigue scores took longer to defibrillate the first time than those with more experience, current critical care experience and low fatigue scores. The interaction showed that participants with more experience, current critical care experience, and high fatigue scores defibrillated the first time in a similar amount of time as those with less experience, current critical care experience and high fatigue scores. This may be because less experience generally equates to younger age, and fatigue may not be as influential in younger nurses. Fatigue may have a more detrimental effect on performance in older nurses. However, in the study by Mertens and Collins (1986) age significantly interacted with workload, but was not impacted by sleeplessness. These researchers also found an interaction of sleep deprivation, workload, and altitude, which is not consistent with the results of the present study. Increasing workload caused a statistically significant decrease in performance in all age groups. The amount of decrease increased significantly with age as well (Mertens, Higgins, & McKenzie, 1983).

The intervention of defibrillation had different results than the other interventions, and the reason is unclear. The researcher expected similar results for the other outcome measures; that high fatigue and less experience would have a negative affect on performance. Perhaps the intervention of defibrillation is the least familiar to clinicians. The other interventions, putting oxygen on the patient, starting IV fluids, assisting with the patient's breathing and intubation, and medication administration, are part of the daily repertoire of critical care interventions.

Hypothesis 2A is supported by the regression results of Critical Care Reaction Time 14. Hypothesis 2A is not supported by the results of the regressions for Critical Care Score, Critical Care Score Percent, Critical Care Errors and Omissions, ANAM Throughput Scores, and the other Critical Care Reaction Times. The interaction of these predictors made a statistically significant contribution to Critical Care Reaction Time 14 (Defibrillates 1st time). Hypothesis 2A is supported by this regression for CCRT14 with the addition of the interaction term.

The researchers in several studies have concluded that sleep deprivation and fatigue are related to decreased performance in clinicians (Gaba & Howard, 2002; Veasy, Rosen, Barzansky, Rosen, & Owens, 2002; Weinger & Ancoli-Israel, 2002). Serious medical errors were related to extended work hours in a study of care provided in intensive care units (Landrigan et al., 2004). Noise is also thought to contribute to fatigue. Listening through static to more than one channel in the noisy environment of the typical cockpit or flight deck is one of the determinants of how soon a crew becomes so fatigued that the mission or safety is affected (USAF School of Aerospace Medicine, 2005b). Altitude and sleep deprivation have been shown to interact, and this interaction was enhanced by increasing workload (Mertens & Collins, 1986). In the present study, Fatigue interacted with Experience and Current Critical Care Experience to negatively influence one critical care reaction time with noise and altitude. The fatigue levels reported by the participants in the noise group are three points lower on a 50-point scale than the average scores of workers reported by the developers of the Fatigue Assessment Scale in two studies (DeVries, Michielsen, & VanHeck, 2003; Michielsen, DeVries, & VanHeck, 2003). The level of fatigue of CCATT clinicians has never been studied. In discussions with critical care nurses that have deployed on CCATTs, fatigue is their main complaint. In a recent study on short-haul airline operations, pilot fatigue was found to be significantly influenced by length of duty, time of day, and number of sectors flown and whether the pilots slept at home prior to departure for duty. The peak fatigue levels were measured after eight hours on duty (Powell, Spencer, Holland, Broadbent, & Petrie, 2007). Frequently CCATT members work in excess of these hours, as they must evaluate the patients for transport, prepare for the flight, and transport the patients to the aircraft prior to the lengthy AE missions. The AE missions often traverse several time zones. During this study, few of the participants had worked prior to participation. Aircraft vibration, along with aircraft motion, noise, and low humidity, may cause discomfort and contribute to travel fatigue (Hinninghofen & Enck, 2006). It is unknown if fatigue scores might be higher during deployment, and therefore exert a greater impact on performance. Even at the low levels, fatigue impacted some parameters of performance when interacting with the other predictors. Fatigue could also be measured before and after the scenarios, to see if it changed during the exposure to the study conditions. It might also be desirable to add another measure of fatigue that is less subjective, such as that taken with a new instrument that measures pupil response to fatigue (Mockensturm, 2001).

In a study by Tourangeau, Giovannetti, Tu and Wood (2002), clinical experience has been shown to have a statistically significant impact on performance as measured by mortality. More years of experience on a clinical unit were predictive of lower 30-day mortality. Priority setting and decision-making have been linked to experience in nurses (Banning, 2007; Hendry & Walker, 2004). Experience has been shown to be a factor in expedient treatment of respiratory failure with continuous positive airway pressure therapy, resulting in improved outcomes (MacGeorge & Nelson, 2003). In this study it was shown that Months of Experience and Current Critical Care Experience interacted with Fatigue to influence one Critical Care Reaction Time. This study included a sample that was possibly more senior than a deploying population of Air Force nurses, and may not reflect the actual experience levels of the population that deploys.

The predictors Experience, Critical Care Experience and Fatigue did not influence Critical Care Scores, Critical Care Percent, or Critical Care Errors and Omissions as hypothesized. Perhaps there are other factors that have more influence on performance with noise and altitude, such as cardiovascular fitness, or experience working in the AE environment.

The regressions for the physiological measures with noise and altitude indicated that Fatigue, Experience, and Current Critical Care Experience did not significantly contribute to physiological performance in this study. Hypothesis 2B was not supported. The results might have been different under different conditions, more closely resembling deployment conditions. It also may be that these factors do not influence physiological performance.

CONCLUSIONS ABOUT THE MODEL FOR THE STUDY

Astrand provided a useful model for this study. The extrinsic factors of noise and altitude were shown to affect the overall performance of the participants during the critical care scenario. Astrand included type of work in his model, and the difficult nature of patient assessment and care were shown to be influenced by altitude and noise, while the cognitive functions tested in the ANAM4 battery were not influenced by altitude and noise. These tests may be less cognitively challenging. Another possibility is that the tests were not sensitive enough to detect changes due to the effects of altitude and noise, or the sample size may have been inadequate, since the study was powered on other outcome variables. Generally, reaction times or time to perform an intervention were not influenced by the environmental factors of noise and altitude. There are many other factors in the model that were not examined in the present study. Performance is very complicated as is evident by the difficulty in measuring it. Different factors other than noise and altitude may influence performance on tests such as the ANAM4.

Astrand's model shows that intrinsic factors influence performance. The intrinsic factors in this study were more influential when they interacted for one critical care reaction time. Astrand's model does not describe interactions of any of the intrinsic or extrinsic factors, but rather shows a simplistic relationship between all of the intrinsic and extrinsic factors affecting performance through the service functions and energy yielding processes. This study revealed that the relationships between the intrinsic factors are more complex than portrayed in the model. Finally, noise and altitude may affect certain aspects of performance and not others. This model does not account for this possibility.

LIMITATIONS OF THE STUDY

A limitation of this study is the use of a simulated environment. Logistical, cost, and mission constraints precluded actual military AE flight from being the study setting. The use of simulation in teaching of healthcare skills has a 20-year history, and assessment of realism scores in anesthesia simulation have been 3.47 out of 4 (Schwid et al., 2005) and 7.8 out of 10 (Devitt et al., 1997). Providing realistic simulations are important to having a study that will have external validity. Efforts to enhance the realism included enclosing the patient care area with photographs of the interior of a military aircraft, and strict adherence to experimental conditions, such as playing the military aircraft noise at the appropriate sound level. Several participants with aeromedical experience commented on the realism of the environment. By selecting a challenging realistic critical care scenario, and closely controlling the intervention conditions, internal validity is increased.

On actual AE missions, all of the stressors of flight would be influencing performance of critical care, but in this study the stressors were limited to just two to allow understanding of the contribution of these two factors to the differences seen in performance. A recent study on the effects of vibration and noise showed vibration of just 44 minutes significantly affected performance, with or without noise (Ljungberg & Neely, 2007). Adding more stressors, while more accurately representing the military aircraft cabin environment, would have greatly increased the complexity of the design and analysis and was not feasible for the present study.

However, since the conclusion of this study, two flight nurses have suggested training missions for reserve AE squadrons might be a platform for future research. Part of the training for medical flight crews is practice of response to patient emergencies.

During CCATT missions, the team may be responsible for one to six patients, though it is typically one to three. Addition of more simulated patients during the study may have changed the results. The complexity of the scenario would have increased, and the attention of the participant would have been divided among the patients. The addition of more simulated patients would have greatly increased the cognitive load on the participant.

Another limitation of this study is that the stress levels of the participants were unknown. A measure of stress, such as cortisol levels, might have added information on another factor that might affect performance. A self-report measure could also have given information on stress levels of the participants.

Another limitation of this study is that while field (senior rank) and company (junior rank) officers were evenly split in the sample, the Air Force Nurse Corps has 29.1% of its nurses at field grade and 66.9% at company grade. The rank and experience composition of the population of nurse corps officers that have deployed is not known, but this sample may not be representative.

Critically ill patients are cared for by teams during AE missions. This study focused on individual performance. Aspects of team performance, such as communication, may lead to different results in the adverse environment of noise and altitude. Within teams, the members can discuss assessment findings and plan together the best course of action for treating the patient. One team member can focus on one aspect of the patient care while the others focus on other considerations. One team member might remember an intervention that the others had forgotten, and communicate this information to the team. This study did not include analysis of many other factors that influence performance. There may be characteristics of the individual or the environment not included, that play an important role.

IMPLICATIONS FOR NURSING

In 2005, 330 patients, 2.4% of all casualties and 11% of battle injuries, required transportation accompanied by a CCATT (Hurd et al., 2006). The United States Air Force is not the only enterprise to use fixed wing aircraft to transport patients. The province of

Quebec in Canada uses an aeromedical evacuation system to transport patients for emergency care and planned specialized treatment because the province spans a very large area and medical treatment facilities are concentrated in Montreal and Quebec City, where the majority of the people live (Gagne, Lavoie, & Frechette, 2006). The Royal Flying Doctor Service in Australia transported 34,000 patients in 2005-2006, and performed 94 aeromedical evacuation *per day* (Royal Flying Doctor Service, 2006). In the United States, several states have fixed wing aircraft to fly patients over long distances for emergency and definitive care. Performance of clinicians in the aircraft environment is an important issue that concerns many people.

Nurses play a pivotal role in the provision of care in the Air Force. The core of the Air Force Medical Service mission is to care for the injured and wounded. This research will improve the capability of the Air Force to accomplish this mission. This research contributes to our understanding human performance of critical care skills by CCATT team members working in the AE environment, and whether interventions to improve quality critical care nursing in the air are requisite for optimal performance.

A study recently published shows that during rest at sea level, the hemoglobin oxygen saturation, measured by pulse oximetry, is slightly but significantly higher in women that in men (Ricart de Mesones, Pages Costas, Viscor Carrasco, Leal Tort, & Ventura Farre, 2007). The authors conclude that while the difference is modest, the other differences between genders, such as the affinity of hemoglobin for oxygen or differences in metabolic rate, may have an impact on altitude ascent, and deserve further study.

Psychological factors that have not been taken into count during this simulation study may affect performance during real missions (Hickman & Mehrer, 2001)

Motivation and stress are just two. There are many factors that affect performance in the Astrand model that deserve further attention in the form of research.

One of the possibilities to consider with the results of the present study related to noise is that performance may have been decreased because of difficulty in assessing the patient and in information gathering processes, and not in the process of cognition. Noise decreased or hampered the information available to the clinician to care for the patient. Audible cues such as patient speech and breath sounds were very difficult to hear during the sessions with noise. Some of the participants gave up trying to assess breath sounds all together, even when the patient's oxygen saturation deteriorated. Many participants treated a pneumothorax that was not present in the scenario because they could not hear breath sounds.

Training of critical care clinicians could also have an impact on performance at altitude with noise. Aspects of care might be improved with training directed specifically at those areas affected by noise and altitude, such as pulmonary assessment.

In the literature on medical alarms, the alarm sounds are of particular focus because this is the primary mechanism to alert the user, and the design and implementation of alarms does not always taking into careful consideration the end user of the system (Edworthy & Hellier, 2006). The AE environment makes recognition of audible alarms very difficult, and requires a paradigm shift to find other ways to alert the clinicians of an alarm situation. Other equipment might be available or developed to enhance audible assessment of patients in the noisy AE environment.

The changes seen in this study in physiological performance may contribute to fatigue during AE missions. The actual impact of the physiological differences at altitude warrants further research.

The researcher observed during the study that some of the participants appeared to be more influenced by the noise or altitude conditions. A few participants complained of developing a headache or having difficulty concentrating during the hypoxic condition. Some participants accurately guessed during which altitude session they had been exposed to 15% oxygen. Other participants could not discern the difference between the altitude conditions, but still displayed lower oxygen saturations during the lower oxygen condition than others under the same conditions. Some participants barely had a drop in oxygen saturation during the altitude condition. A couple of participants said that noise did not bother them at all. Another participant said that he had much trouble staying awake while in an aircraft. Perhaps further study would reveal characteristics of an individual that would make them more or less susceptible to the effects of noise and altitude. This may point to interventions such as physical training or weight management that would better prepare CCATT members for work.

RECOMMENDATIONS FOR FUTURE RESEARCH

The results of the present study have raised questions which should be investigated in future research. These future research questions include the following:

Testing of Variables:

1. What is it about noise that decreases critical care performance? Does noise interfere with assessment or cognitive processing?

2. Is fatigue a significant problem in deployed clinicians, especially those that fly? Is there more fatigue in deployed clinicians than those working in hospitals in the United States?

3. What impact does the increase in heart rate and respiratory rate, and decrease in oxygen saturation have on the individual?

4. Do noise and altitude interact with other stressors of flight?

5. Are there characteristics of an individual that make them more susceptible to the negative effects of altitude?

6. Does baseline physiologic or fitness status make a difference in performance with altitude and noise?

7. Are there gender differences in the affects that noise and altitude have on individuals?

Clinical Practice Issues:

8. Does experience and fatigue play a role in patient outcomes during AE missions?

9. What other factors affect performance of care delivery during deployments?

10. Are self-perceptions of the clinicians and their ability to care for patients during deployment different based on experience?

11. What do clinicians perceive as the biggest environmental and intrinsic factors impacting their practice during AE missions and during deployment?

Research Design and Measurement Issues:

12. Should team performance be measured in addition to individual performance?

13. Would conducting the study on participants after work have yielded different results?

14. Is there a better measure of fatigue relevant to clinical performance?

This research study has provided important information on the effects of altitude and noise on critical care performance. Critical Care Scores, Critical Care Percent, And Critical Care Errors and Omissions were influenced by noise. Transformed respiratory rate was also significantly different with noise. Critical Care Scores, Critical Care Percent, and Critical Care Errors and Omissions were influenced by altitude. Heart rate, transformed respiratory rate, and oxygen saturation were impacted by altitude.

Fatigue and experience did not demonstrate a major effect on performance, although the participants in this study had low levels of fatigue that were surely different than the levels seen by CCATT members that are deployed. The influences of types of experience other than critical care, such as aeromedical evacuation or CCATT, were not analyzed. While providing important information, this research has sparked many more questions about healthcare in austere environments outside hospitals.

APPENDIX 1.

Critical Care Performance in a Simulated Military Aircraft Environment Funded by the TriService Nursing Research Program N06-P02; UM IRB Approval H28539
Fatigue Assessment Questionnaire
Participant Study ID #
Today's Date
Time

Directions:
The following ten statements refer to how you usually feel.
For each statement you can choose one out of five answer categories, varying from Never to Always.
Circle one response for each statement.

1 = Never, 2 = Sometimes, 3 = Regularly, 4 = Often, 5 = Always

		Never	Sometimes	Regularly	Often	Always
1.	I am bothered by fatigue	1	2	3	4	5
2.	I get tired very quickly	1	2	3	4	5
3.	I don't do much during the day	1	2	3	4	5
4.	I have enough energy for every day life	1	2	3	4	5
5.	Physically, I feel exhausted	1	2	3	4	5
6.	I have problems starting things	1	2	3	4	5
7.	I have problems thinking clearly	1	2	3	4	5
8.	I feel no desire to do anything	1	2	3	4	5
9.	Mentally I feel exhausted	1	2	3	4	5
10.	When I am doing something, I can concentrate quite well	1	2	3	4	5

Please complete the following **additional questions** about your sleep, work, and awake hours for the last day:

1. How many hours did you sleep in the last 24 hours? (Fill in) _____ hours

2. How many hours have you been awake? (Fill in) _____ hours

3. How many hours did you work in the last 24 hours? (Fill in) _____ hours

Researcher Signature:	Date:

APPENDIX 2.

Critical Care Performance in a Simulated Military Aircraft Cabin Environment Demographic/Experience Data Form Funded by the TriService Nursing Research Program N06-P02; UM IRB Approval H28539	
Participant Study ID #	
Today's Date	
What is your gender? (Circle one)	Male Female
What is your ethnicity? (Circle one)	Hispanic/Latino Not Hispanic/Latino
What is your race? (Circle one)	American Indian/Native Alaskan
	Asian/Pacific Islander
	Black
	White
	Multi-racial
What is your date of birth? (Fill in)	Month____ Day____ Year______
Military Experience	
What is your branch of service? (Circle)	Air Force Army Navy Guard Reserve
What is your rank? (Circle one)	O1 O2 O3 O4 O5 O6
How many years have you been in the military? (Fill in) Active ________ Reserve______	
Healthcare Experience	
What is your specialty? (Fill in) ____	
How long have you worked in this specialty? (Fill in) ________ years and ________ months	
What other types of experience do you have? (Fill in)	
How long? (Fill in) ______ years and ______ months	

Deployment Experience
Have you been deployed? (Circle) Yes No
How many times? (fill in) ____
What year was your last deployment? (Fill in) ______
How long was your last deployment in months? (Fill in) _____ months
What type of unit did you work in during your last deployment? (Fill in)
____
What type of job did you have during your last deployment? (Fill in)
____
If you transported patients, approximately how many did you transport? (Fill in) ____
Education
What is the highest level of education you have completed? (Circle one)
Associate Degree Bachelor's Degree Some graduate school Advanced Degree
Training
When did you last complete Advanced Cardiac Life Support training? (Fill in)
Date: ______________
Researcher Signature: Date:

APPENDIX 3.

Critical Care Performance in a Simulated Military Aircraft Cabin Environment Health Status/Inclusion and Exclusion Form Page 1 of 3 Funded by the TriService Nursing Research Program N06-P02; UM IRB Approval H28539				
Participant Study ID #				
Today's Date				
To be completed by study participant:				
At the present time, what would you say your health status is? (Circle one)				
Excellent	Very Good	Good	Fair	Poor
Do you have any of the following conditions now? (Circle all those that apply)				
Heart Problems	High Blood Pressure	Lung Problems	History of pneumothorax	
Seizure disorder	Diabetes	Unexplained Loss of Consciousness		
Pregnancy	Anemia	Have given blood in the last 72 hours		
Migraines				
Any other health condition that are not listed?	YES	NO		
Explanation:				

Current prescription medications: Medications you have taken in the last 24 hours: Have you had any caffeine today?   Yes   No What food or drink have you consumed with caffeine? ______________________________
Smoking History
Are you currently a smoker?   (Check one)
____ Yes, I currently Smoke ____ No, I quit within the last 6 months ____ No, I quit more than 6 months ago ____ No, I have never smoked
If you currently smoke: In the last year, how many times have you quit smoking for at least 24 hours? _____
During a typical day, how many cigarettes do you smoke? _____
Researcher signature: **Date:**

Critical Care Performance in a Simulated Military Aircraft Cabin Environment

Health Status/Inclusion and Exclusion Form Page 2 of 3

Participant Study ID # ____________

To be completed by researcher				
Pregnancy Test: ________	Meets inclusion criteria?	YES	NO	NA
Hematocrit: ________	Meets inclusion criteria?	YES	NO	
Exam				
Height: ________	Weight: ________			
BMI________	Meets inclusion criteria?	YES	NO	
Heart Rate: ________	Meets inclusion criteria?	YES	NO	
Blood Pressure: ________	Meets inclusion criteria?	YES	NO	
Respiratory rate: ________	Meets inclusion criteria?	YES	NO	
Head/Ears: WNL Yes No				
Neck: WNL Yes No				
Chest: Lungs CTA Yes No Heart Sounds WNL Yes No				
Abdomen: WNL, no tenderness, no masses Yes No				
Neurological: PERRLA, EOMI Yes No				

Gait, Coordination intact Yes No	
Sensory, motor intact Yes No	
Other findings:	
Exam findings meet inclusion criteria? YES NO	
Meets Inclusion Criteria **YES** **NO** **Meets Exclusion Criteria** **YES** **NO** **Consent Signed** **YES** **NO**	
Researcher Signature:	Date:

Critical Care Performance in a Simulated Military Aircraft Cabin Environment

Health Status/Inclusion and Exclusion Form Page 3 of 3

Participant Study ID #__________

Inclusion Criteria	**Inclusion**
49 years of age or less	☐ Yes ☐ No
Able to read and speak English	☐ Yes ☐ No
Member of the armed services	☐ Yes ☐ No
Willing and able to wear a mask during testing	☐ Yes ☐ No
Willing to have blood drawn/venipuncture	☐ Yes ☐ No
Willing and able to attend one testing session for 3.5 hours	☐ Yes ☐ No
Willing and able to wear earplugs	☐ Yes ☐ No
Willing and able to listen to a recording of aircraft cabin noise	☐ Yes ☐ No
Willing and able to perform 2 simulated patient care scenarios	☐ Yes ☐ No

Exclusion Criteria	**Exclusion**
Hypertension	☐ Yes ☐ No
Respiratory abnormality	☐ Yes ☐ No
Cardiac abnormality	☐ Yes ☐ No
Neurological abnormality	☐ Yes ☐ No
Anemia/hematocrit below 36% for females, 38% for males	☐ Yes ☐ No
Has donated blood in the last 72 hours	☐ Yes ☐ No
Not able or willing to wear mask	☐ Yes ☐ No

Claustrophobia	☐ Yes ☐ No
Not able or willing to wear earplugs	☐ Yes ☐ No
Pregnancy	☐ Yes ☐ No
Unwilling or unable to sign consent document	☐ Yes ☐ No
Other health problems	☐ Yes ☐ No

Meets Inclusion Criteria	**YES**	**NO**
Meets Exclusion Criteria	**YES**	**NO**
Consent Signed	**YES**	**NO**

Researcher Signature: Date:

APPENDIX 4.

Critical Care Performance in a Simulated Military Aircraft Cabin Environment Data Collection Form
Participant Study ID #
Today's Date

FAS Completed YES NO

Group Assignment (circle)
No Noise Noise
Sound Level Meter Reading:

SESSION 1: Ground Level 8000 Feet Altitude O2 Monitor reading:

Time						S													
Heart Rate						T													
Blood Pressure						A													
Respiratory Rate						R													
Oxygen Saturation						T													

ANAM Completed YES NO

Between Sessions

HR ____ BP _____ RR_____ SpO2 ______

Sound Level Meter Reading:

SESSION 2: Ground Level 8000 Feet Altitude O2 Monitor reading:

Time						S													
Heart Rate						T													
Blood Pressure						A													
Respiratory Rate						R													
Oxygen Saturation						T													

ANAM Completed YES NO

Conclusion

HR ____ BP _____ RR_____ SpO2 ______

Researcher Signature	Date:

APPENDIX 5.

Critical Care Performance in a Simulated Military Aircraft Cabin Environment

ACLS Scenario Score Sheet

Funded by the TriService Nursing Research Program N06-P02; UM IRB Approval H28539

Participant Study ID #

Today's Date

Session 1 2 Scenario A B

Information Given/seen by participant	**Time**	**Appropriate Action**	**Completed**	**Time: Total to Task**	**Points: 0 not done 1 done**
Initial State: HR 80, SR, BP 120/82, RR 16, Pulse ox 93	0				
Frame 2: Pt complains of Nausea HR 97, SR, BP 110/70, Normal pulses, pulse ox 93	1:00				
T1		Treats Nausea	☐ Yes ☐ No		
T2		Assesses/Listens to lungs	☐ Yes ☐ No		
Frame 3: Pt Complains of chest pain	2:00				

HR 100, SR, BP 105/65, RR 22, pulse ox 89, Periph pulses weak, central pulses NL					
T3		Treats CP/MSO4/NTG/ASA	☐ Yes ☐ No		
T4		Puts on oxygen	☐ Yes ☐ No		
Frame 4: HR 111, SR with PVCs, BP 108/66, RR 22, Pulse ox 89	3:00				
Frame 5: HR 120, Unifocal PVCs 29 per min, BP 90/50, RR 34, Pulse ox 84, pulses weak	4:00				
T5		Hangs IV fluids	☐ Yes ☐ No		
Frame 6: HR 130, SR with PVCs 30 per min, BP 70/40, RR 8, pulse ox 75	5:00				
T6		Starts BVM breathing	☐ Yes ☐ No		
T7		Intubate/Advanced Airway	☐ Yes ☐ No		
T8		Checks for placement Listening End-tidal CO2	☐ Yes ☐ No		
T9		Vasopressors	☐ Yes ☐ No		
T10		Second bag of IV fluid	☐ Yes ☐ No		
Frame 7: Vtach, unstable, HR	6:00				

180, BP 70/40, Pulse on 70, RR 8					
T11		Checks pulse/feels pulse present	☐ Yes ☐ No		
T12		Cardioverts correctly	☐ Yes ☐ No		
Frame 8: VT HR 180, BP 20/10, No pulse, Unresponsive, Pulse ox 0, RR 8 with bagging	7:00				
T13		Starts CPR	☐ Yes ☐ No		
T14		Defibrillates 1st time	☐ Yes ☐ No		
Frame 9: Vtach HR 180, pulse ox 0 BP 0, RR 8, no pulses	7:30				
T15		Gives epinephrine 1 mg or Vasopressin 40 U IV	☐ Yes ☐ No		
Frame 10: VFibm no VS, RR 8 with bagging	8:00				
T16		Gives Amiodarone 300 mg IV or Lidocaine, 1.5 mg/kg IV	☐ Yes ☐ No		
Frame 11	10:00				
Frame 12: Brady, HR 54, SR 2nd degree AV Block type 2, weak pulse, respirations 16, BP 75/54	11:00				

T17		Checks pulse	☐Yes ☐No		
T18		Atropine 0.5-1.0 mg iv push	☐Yes ☐No		
Frame 13: SR Post ischemia, HR 104, unifocal PVCs 0 per min, BP 70/54, pulses weak, Pulse on 98 on 100%, RR 16 with bagging and spont breathing	13:00				
T19		Starts amiodarone or lidocaine drip	☐Yes ☐No		
Frame 14: SR Post ischemia HR 111, BP 86/52, RR 12 with assist, pulse ox 96 on 100 %, weak pulses	15:00				
Frame 15: SR post ischemia, HR 125, decreased breath sounds, pulse ox 90, BP 82/50	15:30				
Frame 16: SR with ischemia, HR 143, BP 80/50, RR 40, O2 sat 76, no breath sounds, increased resistance	16:00				
T20		Reintubates	☐Yes ☐No		
T21		Checks for placement	☐Yes ☐No		

		Listening End-tidal CO2			
Frame 17: SR Post Ischemia, HR 120, pulse ox 92, BP 100/65	18:00				
Frame 18: SR post ischemia, HR 111, BP 110/70, airway patent, RR 12, pulse ox 98, normal pulses	19:00				
T22		Stabilizes	☐ Yes ☐ No		
Conclusion	20:00				

Score ____ out of a possible 22

Percent Score _____

Incorrect Actions______ (Needle decompression/chest tube)

Researcher signature:	Date:

APPENDIX 6.

Critical Care Performance in a Simulated Military Aircraft Cabin Environment

Dissertation Research
By
Margaret M. McNeill
Researcher
University of Maryland
If you are interested in participating in this study

Please Contact:
Margaret McNeill
mmcne002 @umaryland.edu

PURPOSE AND DESCRIPTION OF THE RESEARCH
You are being invited to join in a research study to evaluate the effect that aircraft cabin environmental conditions have on the performance of military healthcare personnel as they transport patients.

The purpose of this study is to identify whether altitude and aircraft noise have an effect on performance of nurses and physicians as they take care of critically ill patients during aeromedical evacuation.

This information will be used to
inform AE medical equipment design, training and policy. The information will also help to improve work performance of Critical Care Air Transport Teams during aeromedical transport, thereby positively impacting patient safety and outcomes, as well as operational readiness. Sixty-six people are anticipated to participate in this study.

mmcne002 @umaryland.edu

Before the study…
The study requires participants to meet health requirements of operational support flight duty. Prior to the first session you will answer health questions, and have your height and weight measured. A physical exam will be completed by the researcher, a Clinical Nurse Specialist. The self-report health questionnaire and physical exam must not show any cardiovascular, respiratory, neurological, abdominal, or other abnormalities. Health problems that prevent critical care transport team duty exclude participation.

Part of the physical exam is a blood hematocrit measurement. Female participants must have a hematocrit above 36%; male participants must have a hematocrit above 38%.

In order to measure your hematocrit, a small amount of blood, about one teaspoonful, will be drawn from your arm by a nurse at the beginning of your first session. You will be seated when your blood is taken. If you have a low hematocrit, you will not be asked to do the testing. You will be advised to make an appointment with your healthcare provider.

If you are female, you will be asked to give a urine sample for pregnancy testing. If you are pregnant, you will not be asked to do the testing. You will be advised to make an appointment with your healthcare provider.

Other baseline data collected will be your experience, fatigue level, and information about you such as age, race, ethnicity, gender, service, etc.

During the Study…
During the testing sessions, you will wear a mask that will be delivering air for you to breathe at either ground level or 8000 feet altitude oxygen levels. This is the altitude that an aircraft is pressurized to even though it is flying much higher.

During the sessions, the sounds from a C-17 aircraft may be played. You will be instructed on how to properly insert earplugs for hearing protection. You will remain at the test conditions for 60 minutes during each session, during which you will provide care in a simulated patient scenario.

During both sessions you will be providing care to a simulation manikin. The monitors attached to the manikin will be showing the "patients" vital signs and condition.

Your vital signs will be continuously monitored, and recorded every five minutes. These two sessions will be video recorded for later viewing and analysis by the Principal Investigator.

During each session you will also complete The Automated Neuropsychological Assessment Metrics to see if the conditions have an affect on your thinking abilities.

After the study
Your information will remain confidential

You will receive a check in the mail

How Much Time Will It Take?
The study will require three and one-half hours of your time, split into two testing sessions. You will have a 15-minute break in between each session. Once you sign the consent form you will be enrolled in the study.

Will I be Paid?
Participants that complete the study will be paid $50

WHERE DO I HAVE TO GO?

The study will take place at the University of Maryland School of Nursing in downtown Baltimore. Transportation and parking are available.

The address is

655 West Lombard Street

Baltimore, MD 21201

mmcne002 @umaryland.edu

Critical Care Air Transport

- 29,000 total casualties transported in 2005
- Critical Care Air Transport Teams provided intensive care in the air
- Military Cargo Aircraft
  - C-130
  - C-17
  - C-141
- Stressors of Flight
  - Hypoxia
  - Hypobaric pressure
  - Decreased humidity
  - Temperature fluctuations
  - Noise
  - Vibration
  - Fatigue
- These stressors affect both patients and healthcare personnel

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UM IRB APPROVAL H-28539
79th MG APROVAL FMG2007-0002H

APPENDIX 7.

Risks

Finger stick for hematocrit	**MINIMAL:** The risks associated with the finger stick are pain, and bruising at the site.
Altitude simulation with mask	**MINIMAL:** The risks associated with the healthy volunteers that are physically qualified to be CCATT members to experiencing oxygen levels of cabin altitude of 8,000 are minimal, and are no different than the normal working conditions of all CCATT, air crew members, and passengers during commercial flight. Participants were continuously monitored. Testing would have been stopped if the participant displays a pulse oximeter reading below 85% and a heart rate above 130. Oxygen and an automated external defibrillator were available. An Advanced Cardiac Life Support provider was present during all testing. Emergency phone number were immediately accessible.
Noise	**MINIMAL:** The noise levels of fixed wing military aircraft was simulated, and the volunteers used the standard ear plugs that are issued for CCATT patient movement to protect hearing. The time of exposure was approximately 120 minutes, keeping the risk at minimum.
Respiratory rate monitoring	**MINIMAL:** The risks associated with the respiratory monitor were that the pads might have been slightly uncomfortable on the chest, and when removed.
Heart rate monitoring	**MINIMAL:** The risks associated with the heart rate monitor were that the pads might have been slightly uncomfortable on the chest, and when removed.

Oxygen saturation/ Pulse oximetry monitoring	**MINIMAL:** The risks associated with the SpO2 measurement were minimal and involved monitoring oxygen saturations with a forehead or ear probe.
Blood Pressure monitoring	**MINIMAL:** The blood pressure cuff applied pressure to the arm briefly. There was minimal risk for bruising with cuff inflation.
Simulation of critical care tasks	**MINIMAL:** The volunteers performed the tasks required to manage a simulated critically ill aeromedical evacuation patient. This involved minimal risk.
Questionnaires and cognitive assessment	**MINIMAL:** The volunteers completed three questionnaires and a neurocognitive assessment that have no identifiable risks. The PI was available at all times to address questions or concerns of the participants.
Potential breach of confidentiality	**MINIMAL:** There is the potential risk of loss of confidentiality. To protect participants' confidentiality and privacy, names were not attached to test results. The results are only identifiable by a unique code which allows statistical analysis and data matching. Documents, videotapes, and computer files are kept in a locked file cabinet in the researcher's office. Videotapes have only been viewed by the investigators and do not have the participants name on them. Computer data is fingerprint and password protected. All participants' research records will be kept confidential. Participants will not be identifiable in any publications or reports on the study or data. The investigator is available at all

	times to address questions or concerns of the participants.

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